

Editorial

Apple Industry Evolves to Meet Market, Environmental, and Regulatory Challenges Through Science

I grew up visiting my grandparents' farm every weekend and listening to my grandfather talk about his crops and livestock. One thing that has always stuck with me was his resilience and his ability to adapt when things became challenging. Now, in my position as executive director of the Michigan Apple Committee, I see the same resilience and the embracing of change in the apple growers I work for.

There are so many new and exciting things happening in the apple industry and they are all about investing for the future. First are the renewed investments in our land grant university, Michigan State University. Growers in our state are committed to being vested partners with the university in making our state research stations centers of excellence. New and ground-breaking research is taking place at these stations, in part because of the monetary investment of 32 cents per bin our growers have made.

Second, supporting current staff and courting new and excellent researchers and extension educators working on behalf of those land grant universities is vital. Directing the industry needs into research can be challenging at times. Our industry has the possibility of endless projects and very limited resources. This is why it is so important to maintain the researchers that are doing a great job of finding multiple funding sources, and we need those extension educators that tirelessly try to incorporate that research on the farms.

Science is driving everything – varietal improvements, technology, consumer trends, and on and on. Science, whether good or bad, is influencing consumers daily on social media platforms. Like it or not, this is where consumers get their information, and dispelling incorrect information can be challenging. The need for continued research and extension work will be invaluable going forward, as they are the “experts” and have the credibility we need to answer those questions from consumers. Who knew the science helping you grow a great product would also be what consumers want or need to hear about?

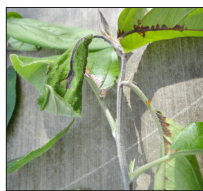
Apple consumption continues to rise, and retailers are responding with increased display space and marketing programs, during harvest and beyond. Researchers and extension educators who provide us with scientific information that we can use to engage with consumers are invaluable. Conversations online, in the media, and face-to-face that are backed by facts allow us to continue to encourage consumption of apples.

Looking ahead, we see that new challenges await. More stringent state and federal regulations, trade issues and, of course, labor, will continue to present new obstacles for the industry to overcome. I am inspired by growers, industry leaders and researchers across the country and across the globe who are already seeking ways to address these challenges.

Continued on page 2



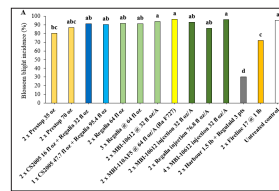
5



13



21



25



31

Contents

5 On-Farm Evaluation of Apple IPM Protocols in the Champlain Valley

Anna Wallis, Arthur Agnello, and Harvey Reissig

13 Wild apple species as a source of fire blight resistance for sustainable productivity of apple orchards

Awais Khan and Thomas Chao

21 Red-juiced apple cultivars for Great Lakes production

Steve van Nocker and Chris Gottschalk

25 Evaluation of newer biologicals and the SAR-activator candidate Regalia in fire blight control applied by spraying or trunk injection

Srdan G. Aćimović and Christopher L. Meredith

31 Expanding the Range of the Samurai Wasp, *Trissolcus japonicus*, in New York Orchards

Peter Jentsch

COVER: Red-fleshed apple cultivars under evaluation for production in the Great Lakes region

NEW YORK STATE HORTICULTURAL SOCIETY

- President** **Ned Morgan**, Morgan Farms LLC
3131 Pigeon Hill Road, Marion, NY 14505
Cell: 585-752-9771; FAX: (315) 926-7740
email: emorgan11@rochester.rr.com
- Vice President** **Ted Furber**, Cherry Lawn Farms
8130 Glover Road, Sodus, NY 14551
PH: 315-483-8529; FAX: 315-483-6408
Cell: (315) 573-4046
e-mail: atfurber@yahoo.com
- Treasurer/Sec.** **Ward Dobbins**, H.H. Dobbins & Son
99 West Ave., PO Box 503, Lyndonville, NY 14098
PH: (585) 765-2271; FAX: (585) 765-9710
Cell: (716) 622-6636
e-mail: wdobbins@wnyapples.com
- Executive Director** **Paul Baker**
3568 Saunders Settlement Rd., Sanborn, NY 14132
FAX: (716) 219-4089; Cell: (716) 807-6827
e-mail: pbaker.hort@roadrunner.com
- Office Admin.** **Karen Wilson**
630 W. North St., Geneva, NY 14456
PH: (315) 787-2404 (W); FAX: (315) 787-2216
Cell: (315) 521-0852
e-mail: wilsonk36@hotmail.com
- Cornell Director** **Dr. Art Agnello**, NYSAES, Department of Entomology
630 W. North St. Geneva, NY 14456
PH: (315) 787-2341 (W); FAX: (315) 787-2326
Cell: (315) 719-4623
e-mail: ama4@cornell.edu
- Director** **Dan Sievert**, Lakeview Orchards, Inc.
4941 Lake Rd., Burt, NY 14028
PH: (716) 778-7491 (W); FAX: (716) 778-7466
CELL: (716) 870-8968
e-mail: lvorchards@hotmail.com
- Director** **John Ivison**, Helena Chemical Company
165 Platt St., Suite 100, Albion, NY 14411
PH: (585) 589-4195 (W); FAX: (585) 589-0257
Cell: (585) 509-2262
e-mail: ivisonj@helenachemical.com

- Director** **Alisha Albinder**, Hudons River Fruit Distributors
65 Old Indian Road, PO Box 246, Milton, NY 12547
PH: (845) 795-2121; FAX: (845) 795-2618
Cell: (845) 518-3962
e-mail: alisha@hudsonriverfruit.com
- Director** **Randy Hart**, Hart Apple Farms, LLC
2301 Rt. 22, Peru, NY 12972
Cell: (518) 524-5366
e-mail: randy.hart1@gmail.com
- Director** **Elizabeth Madison**
5812 Middle Road, Sodus, NY 14551
PH: (315) 483-6155
e-mail: emadison1234@gmail.com
- Director** **Brett Kast**, Kast Farms, Inc.
2911 Densmore Road, Albion, NY 14411
PH: (585) 589-9557
e-mail: Brett.Kast@gmail.com
- Director** **Joel Crist**, Crist Bros. Orchards
65 Crist Lane, Walden, NY 12586
PH: (585) 778-7424 Cell: (845) 629-0761
e-mail: joel@cristapples.com
- Director** **Richard Breslawski**, Charles Breslawski Farm
501 Priem Rd., Hamlin, NY 14464
Cell: (585) 831-0643
e-mail: richih1256@hotmail.com

APPLE RESEARCH & DEVELOPMENT PROGRAM ADVISORY BOARD

- Chairman** **Walt Blackler**, Apple Acres
4633 Cherry Valley Tpk. Lafayette, NY 13084
PH: 315-677-5144 (W); 315-729-3728 (C)
wblackler@gmail.com
- Alan Buhr**, New Royal Farms
7577 Slayton Settlement Road, Gasport, NY 14067
PH/FX: 716.772.2469; greenapple47@juno.com
- Steve Clarke**, Sunshine Orchards
40 Clarkes Lane, Milton, NY 12547
PH: 845-795-2383; 845-901-7440(C); FX: 845-795-2383
apelsteve@hvi.net
- Robert Deemer**, Dr. Pepper/Snapple Group
4363 Rte.104
Williamson, NY 14589
PH: 315.589.4911 ext. 713; FX: 315-589-8048
bob.deemer@dpsg.com
- Mason Forrence**, Forrence Orchards
2740 Route 22, Peru, NY 12972
PH: 518-643-9527; 518-726-6074 (C); FX: 518-643-9509
gaylewager@yahoo.com
- Ted Furber**, Cherry Lawn Farms
8099 Glover Rd., Sodus, NY 14551
PH: 315-483-9221; 315-573-4046 (C); FX: 315-483-6408
atfurber@yahoo.com
- Mark McMullen**, Marketing Order Administrator
NY State Dept. of Agriculture & Markets
108 Airline Drive, Albany, NY 12235
PH: 518-485-2014; FX: 518-457-2716
mark.mcmullen@agriculture.ny.gov
- Jeff Smith**, Ledge Rock Farms LLC
4362 South Gravel Road, Medina, NY 14103
PH: 585-798-3831
jsmith24@rochester.rr.com
- Peter Ten Eyck**, Indian Ladder Farms
342 Altamont-Voorheesville Road
Altamont, NY 12009
PH: 518-765-2956; 518-698-6258 (C); FX: 518-765-2700
Peter@indianladderfarms.com

MICHIGAN APPLES BOARD MEMBERS

- Chair** **Tony Blattner**
Lowell, MI
- Vice Chair** **Mark Youngquist**
Kent City, MI
- Executive Committee Members**
- Mike Dietrich**
Conklin, MI
- Damon Gleis**
Hillsdale, MI
- Robert Gregory**
Leland, MI
- Art Lister**
Ludington, MI
- Jeremy Shank**
Dowagiac, MI
- Executive Director** **Diane Smith**
Michigan Apple Committee
13750 S. Sedona Parkway, Suite 3
Lansing, MI 48906
Ph. 800.456.2753 Fax 517.669.9506



Editorial, Continued

The ability to adapt to changes from the growing, harvesting, packing, regulatory and marketing standpoints will continue to be the key to success of the produce industry. The only constant is change, and I am confident that the industry is well equipped to face the challenges and advances to come.

Diane Smith
Michigan Apple Committee
Diane@MichiganApples.com

NYS BERRY GROWERS BOARD MEMBERS

- Chair** **Dale Riggs**, Stonewall Hill Farm
15370 NY Rt 22, Stephentown, NY 12168
PH: 518-733-6772; stonewallhill@taconic.net
- Treasurer** **Tony Emmi**, Emmi Farms
1572 S. Ivy Trail, Baldwinsville, NY 13027
PH: 315-374-3577; emmifarms@aol.com
- Executive Secretary** **Paul Baker**
3568 Saunders Settlement Rd., Sanborn, NY 14132
CELL: 716-807-6827; FAX: (716) 219-4089
pbaker.hort@roadrunner.com
- Bruce Carson**, Carson's Bloomin' Berries
2328 Reed Rd.
Bergen, NY 14416
PH: 585-494-1187; bcarson1@frontiernet.net
- John Cashin**, Cashin Farm
225 Argersinger Road, Fultonville, New York 12072
PH: 518-281-6000; cashinsfarm.com
- Amy MacHamer**, Hurd Orchards
17260 Ridge Rd., Holley, NY 14470
- Elizabeth Madison**
5812 Middle Road, Sodus, NY 14551
PH: (315) 483-6155; emadison1234@gmail.com
- Terry Mosher**, Mosher Farms
RD #1 Box 69, Bouckville, NY 13310
PH: 315-893-7173; tmosher@directway.com
- Chuck Mead**, Mead Orchards LLC
15 Scism Rd., Tivoli, NY 12583
PH: 845-756-5641 (W); CELL: 845-389-0731
chuck@meadorchards.com

WINTER 2017 • VOLUME 25 • NUMBER 4

This publication is a joint effort of the New York State Horticultural Society, Cornell University's New York State Agricultural Experiment Station at Geneva, the New York State Apple Research and Development Program, Michigan Apple Committee, and the NYSBGA.

- Editor** **Dr. Art Agnello**
Dept. of Entomology
New York State Agricultural Experiment Station
Geneva, NY 14456
PH: 315-787-2341; FX: 315-787-2326
CELL: 315-719-4623
ama4@cornell.edu
- Subscriptions & Advertising** **Karen Wilson**
NYSHS, 630 W. North St., Geneva, NY 14456
PH: 315-787-2404; FAX: 315) 787-2216
wilsonk36@hotmail.com
- Design** **Elaine L. Gotham**
Gotham City Design, Naples, NY
PH: 585-374-9585; elg2@cornell.edu
- Production** **Gemma Osborne**
CAL Communications
NYSAES, Geneva, NY
PH: 315-787-2248; gro2@cornell.edu

SAVE THE DATES!

Empire State Producers Expo

EXPO



2018

January 16-18, 2018

**SRC Arena & Events Center (new location)
Syracuse, NY**

Becker Forum on January 16, 2017

Holiday Inn, Liverpool

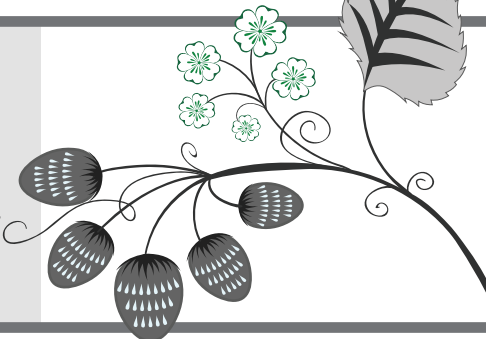
See page 20 for details.



NOURSE

The Best Berry Plants Since 1932

*Strawberry
Brambles
Asparagus
Blueberry
Currant
Gooseberry
Elderberry
Rhubarb*



**THE LEADING
SMALL FRUIT NURSERY TODAY!**

- *Excellent Customer Service*
- *Wide Variety Selection*
- *Technical Support*
- *Complete Lab Facility for
Tissue Culture & Virus Indexing*

41 River Road South Deerfield MA 01373
413.665.2658

noursefarms.com info@noursefarms.com



Since 1884

MUNCKHOF

3 Row Orchard Sprayer

**Do your spraying job in
1/3rd of the time**

**Savings on labor, fuel
and tractor hours**



LaGasse Works, Inc.

(888) 946-9202

works@lagasseworks.com

**5 Old Route 31
Lyons, NY 14489**



Imidan® 70-W

Agricultural Insecticide

BROAD SPECTRUM

+ COST EFFECTIVE

Good fit for IPM and insecticide rotation management

Wide set of global MRLs makes it easier to sell your crop to many export destinations

CROP	PHI	PEST SPECTRUM
Apple	7 days	Apple Maggot, Codling Moth, Sawfly, Curculio, + 14 other insect pests.
Tart Cherries	7 days	Curculio, Spotted Wing Drosophila + 6 other insect pests.
Blueberries	3 days	Blueberry Maggot, Spotted Wing Drosophila + 14 other insect pests.

Gowan
USA
800.883.1844 GOWANCO.COM

Imidan® is a registered trademark of Gowan Company, L.L.C. EPA Reg. No. 10163-169. Always read and follow label instructions.

On-Farm Evaluation of Apple IPM Protocols in the Champlain Valley

Anna Wallis¹, Arthur Agnello², and Harvey Reissig²

¹Cornell Cooperative Extension, Eastern NY Commercial Horticulture Program, Plattsburgh, NY

²Dept of Entomology, Cornell University, New York State Agricultural Experiment Station, Geneva, NY

Pest management is one of the most expensive and time-consuming responsibilities of operating an orchard. Unfortunately, it is also a moving target. Over the past two

“The goal of this work was to fill in the gaps in knowledge in Northeastern NY about insect pest pressure and management, by documenting insect pest populations and pressures, testing an IPM protocol in on-farm situations, and providing grower training to support IPM implementation on farms in the region.”

decades, changes in the landscape of Northeastern NY orchards have made it increasingly challenging for growers in the region to manage economically significant pests. Such changes have included changing to

new rootstocks, implementation of new tree training systems, restrictions on chemical controls, changing climate, and introduction of pests from other areas (Agnello and Reissig 2010; Robinson et al. 2013, 2014; Bebbier 2013).

According to observations by growers, consultants, and other industry members, insects have become increasingly difficult to control in Northeastern NY. Reports have included increasing populations and occurrence of later generations, resulting in more frequent fruit damage and bin rejections. For example, obliquebanded leafroller (OBLR), which historically required little or no targeted control, became a serious pest in the 1990s and wreaked havoc on the majority of operations in the Champlain Valley (J. Eve, personal communication, Aug 2014) (Figure 1). Over the course of only a few years, OBLR-specific scouting and pesticides became the norm, and the insect continues to be the driving force behind most summer insect management programs. Codling moth and oriental fruit moth are other insects that have previously required less intensive control measures in the Champlain Valley as compared with other apple production regions in the Northeast. However, increasing trap captures and fruit damage in both NY and VT, and observations of later generations have forced growers and consultants to track these pests more closely and alter programs accordingly (J. Eve, personal communication, August 2014).

The cause of these changes is complicated and doubtless the result of multiple factors. A warming climate is likely expanding insect ranges and facilitating their overwintering farther north (Bebber 2013; Aćimović 2017). Considerable changes have been made in rootstocks, varieties, and training systems (Robinson 2013, 2014), which may be favoring insect populations and making new plantings more susceptible to damage.



Figure 1. Insect damage from summer feeding of obliquebanded leafroller (A) and early season lepidopteran damage (B) at orchards in Clinton County, NY. OBLR has become an economically significant pest in the Champlain Valley in the past 10–15 years. [Photos: A. Wallis]

Movement of plant material, bins, and fruit to and from the region has the potential to introduce or increase insect populations (APHIS 2010; Aćimović 2017). Also, changes in chemical controls have complicated management. Movement away from traditional broad-spectrum materials with long residual and high mammalian toxicity (e.g., organophosphates, carbamates) to more pest-specific, less persistent chemistries limits the tools available for insect control, and requires growers to spend more time learning these new products and making more informed, targeted pesticide applications (Agnello and Reissig 2010; Jentsch 2017).

Fortunately, there is a plethora of information available to aid growers in insect pest management decisions. These resources include fact sheets and trapping protocols developed by Cornell, web-based monitoring systems such as the Network for Environment and Weather Applications (NEWA), and advising by private consultants. In addition, a thorough insect IPM (integrated pest management) protocol was developed in the early 2000s using web-based resources (Agnello and Reissig, 2010).

However, there has been a gap in knowledge in Northeastern NY about insect pest pressure and management. Lack of resources allocated to the region, distance from main agricultural experiment stations, and a gap in extension personnel in the area resulted in missing or poor documentation of pest pressure and implementation of sustainable pest management strategies. Often, orchardists lack extensive knowledge of the biology of these pests and expertise in using these resources, often relying

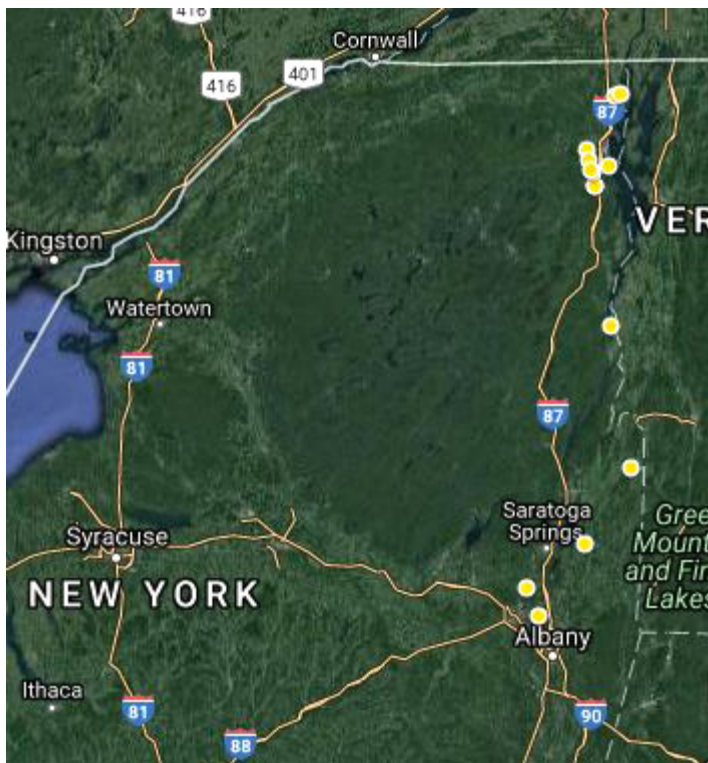


Figure 2. Insect monitoring sites in Northeastern NY.

heavily on private industry consultants with limited resources. Furthermore, technology barriers and training time required have prevented many farmers from adopting the system.

The goal of this work was to fill in these gaps by documenting insect pest populations and pressures in Northeastern NY, testing an IPM protocol in on-farm situations, and providing grower training to support IPM implementation on farms in the region.

Methods

Blocks were established at 5–12 sites in 2015, 2016, and 2017 on commercial orchards in Northeastern NY (Figure 2)

to trap and scout for economically significant insects: codling moth (CM), oriental fruit moth (OFM), obliquebanded leafroller (OBLR), apple maggot (AM), leafhoppers, mites, aphids, and scales. Traps were monitored and sites were scouted weekly throughout the growing season, beginning in mid-April until harvest in early September (Figure 3).

At five sites in 2015, paired “IPM” and “Control” blocks were established, approximately 1–5 acres in size, of the same or very similar variety, rootstock, age, training system, etc. Blocks were selected that were planted with Honeycrisp and McIntosh, the most commercially important varieties produced in this region, and modern high-density plantings of mature bearing age. Recommendations were given to growers weekly for IPM blocks. A summary of pests, target life stages, and management thresholds is summarized in Table 1. Control blocks were to be managed at the growers’ discretion, according to their normal program, to represent a grower standard. They were asked not to intentionally replicate the IPM management program if possible.

Overarching goals of the IPM program included:

- **Thresholds:** Pesticide applications were only recommended once pests or damage were detected above a pre-determined economic threshold (i.e., trap numbers or leaf/fruit damage).

Table 1. IPM Program general outline including target pests, life stages, and management thresholds.

Insect	Target life stage	Threshold or Activity
ERM	- Eggs	- Dormant oil
PC	- Adults moving into orchard until - 40% oviposition	- PF spray - More sprays until 308 DD50
OFM	- 1 st gen larvae - 2 nd gen larvae	- 350-375 DD45 from biofix - 175-200 DD45 from 2 nd flight
CM	- 1 st gen larvae - 2 nd gen larvae	- 250-360 DD50 from biofix - 250-350 DD50 from 2 nd flight
OBLR	- Overwintered brood - Summer brood	- 3% infestation of bud clusters - Rate fruit at 600 DD43 from biofix, - 1 damaged fruit
AM	- First migrating flies - Subsequent sprays	- 5 flies per trap (average of 3 traps) - 5 flies per trap or 10-14 days



Figure 3. Insect traps used for monitoring. (A) Delta traps with pheromone lures deployed for codling moth, oriental fruit moth, and obliquebanded leafroller. (B) Sticky card with pheromone lure, obliquebanded leafroller trap. (C) Apple maggot sticky red sphere trap with volatile apple essence lure, in an orchard in Clinton County. Lures are deployed at the beginning of July near the orchard edge, near other host trees (e.g., hawthorn), if present. [Photos: A. Wallis]

- **Timing:** Pesticide applications were made based on insect activity to target the most susceptible life stage.
- **Materials:** Pesticides used were considered more “IPM-friendly”: more pest-specific, lower mammalian toxicity, shorter persistence in the environment.

To evaluate efficacy of the IPM protocol compared with the grower standard, insect damage was evaluated at harvest. A sample of 600 fruits from each site (200 from the center of the orchard block, 100 from each side of the block) was evaluated for type of insect damage, and packing-line grade (clean, fancy, #1, or cull). Insect damage was compared against pesticide records and pest activity to determine which pests were effectively or insufficiently managed.

We attempted to replicate the work done in 2015 evaluating the efficacy of the insect IPM protocol. Due to the following circumstances, we were unable to follow it through the 2016 and 2017 seasons:

- Grower collaborators were often already using the IPM protocol in some capacity, so spray timings and materials were the same for IPM and Control treatments. We observed that pest management decisions were based heavily on recommendations provided by extension publications, web-based models, and/or private consultants’ recommendations, which were informed by models and extension protocols.
- Grower collaborators used the recommendations given for “IPM treatment” blocks to make decisions about the “Control” blocks. Therefore, paired blocks received the same treatments.
- Growers in the Champlain Valley experienced extraordinary weather and disease challenges during the 2016 season. Therefore, they were unable to provide labor, time, and/or more expensive materials necessary to implement the IPM treatments.

To determine if treatments applied in 2015 had a carryover effect for the 2016 crop, insect damage was evaluated 1) in late spring and 2) at harvest. In late May, 600 terminals were sampled for OBLR infestation (200 from the center of the block, 100 from each side). At harvest, a sample of 600 fruits was again taken from each site (200 from the center of the orchard block, 100 from each side of the block) and was evaluated for type of insect damage, and packing-line grade. Insect damage was compared against pesticide records and pest activity to determine which pests growers effectively managed, and which were not effectively controlled.

Results & Discussion

Insect flight patterns

Flight patterns of oriental fruit moth (OFM), codling moth (CM), and obliquebanded leafroller (OBLR) were variable between years and sites, as illustrated in Figure 4, showing trap captures at sites in the Champlain Valley where we monitored in each year.

OFM biofix occurred in mid- to late May in all three seasons (18–23 May), at approximately 400–465 DD43. This is later than the average biofix observed in Geneva over the past 33 years, (223–324 DD43), corresponding to an average calendar date of 2 May (Agnello 2017a). The discrepancy may be due to low insect populations in Northeastern NY and therefore low detection. Trap catches throughout the season indicate approximately three generations. Timing of these generations varied considerably by

year and are likely related to seasonal conditions. While moth activity appeared to cease after mid-summer in 2017, we continued to detect insects into September during 2015 and 2016. This indicates the need for continued scouting and possible management closer to the harvest date.

CM biofix occurred in late May (25–30 May), at approximately 560–590 DD43. This is slightly later than average Geneva observations over the past 35 years: first catch 396–566 DD43 and average calendar date of 18 May (Agnello 2017b). The patterns of CM catch generally followed the same pattern observed in other regions of NY (Breth 2010). Trap captures indicated an “A” and “B” peak for the first generation flight and a second generation flight. The considerable variability in moth number and flight pattern (relative size of A and B peaks, for example) between sites is not unusual, and justifies site-specific monitoring and management.

OBLR biofix ranged from 1–20 June, at approximately 730–1003 DD43, consistent with the Geneva average first catch: 795–980 DD43 (Agnello 2017c). A clear 1st peak flight was observed in late June to early July each year at most sites. A slight increase in trap captures was observed early in September. This may be related to reduced insecticide applications approaching harvest. Alternatively, it may indicate the presence of later generations, as the result of longer, warmer growing seasons. Therefore, monitoring insects through the beginning of September is advised in order to detect insect pressure close to harvest.

In 2017, we included an abandoned, unmanaged orchard site. CM trap captures at the abandoned site were much higher than at commercial sites. This could indicate that managed orchard sites are “clean” (i.e., growers have excluded or effectively managed these insects). We did not observe this discrepancy for the other moths we monitored.

For all three insects (OFM, CM, and OBLR), we expected that we might observe lower trap captures, fewer generations, and lower pressure as compared with other regions of NY, due to geographic isolation, colder winters, and shorter growing season. However, we observed very similar patterns and generation numbers, with slight (expected) delays in emergence in the spring. We observed great variability among sites for all insects. This and the foreseeable change in orchard landscape factors (climate, introduction of pests, management tools) substantiate the need for continued monitoring of multiple sites in Northeastern NY, to detect changes in regional patterns, and to provide site-specific management recommendations.

IPM Protocol: Fruit Damage

In both 2015 and 2016, we found very little difference in the percent damaged fruit between the IPM and Control blocks (Table 2). In 2015, the total number of damaged fruit in both IPM and Control blocks averaged less than 3%. In 2016, insect damage in fruit evaluated at harvest at all sites and in both treatments was less than 2% for any particular insect. This is well below the 5% damage typically tolerated in the packing line.

With respect to fruit grade, we also observed very little difference between treatments (Table 3). In 2015 an average of 96.3% of fruit from Control blocks and 96.0% of fruit in IPM blocks were clean (no insect damage at all). In 2016, nearly all fruit were again classified as clean in both the grower standard, with an average of 100%, and 96.4% clean in Control and IPM blocks, respectively. Both treatments during both seasons exhibited

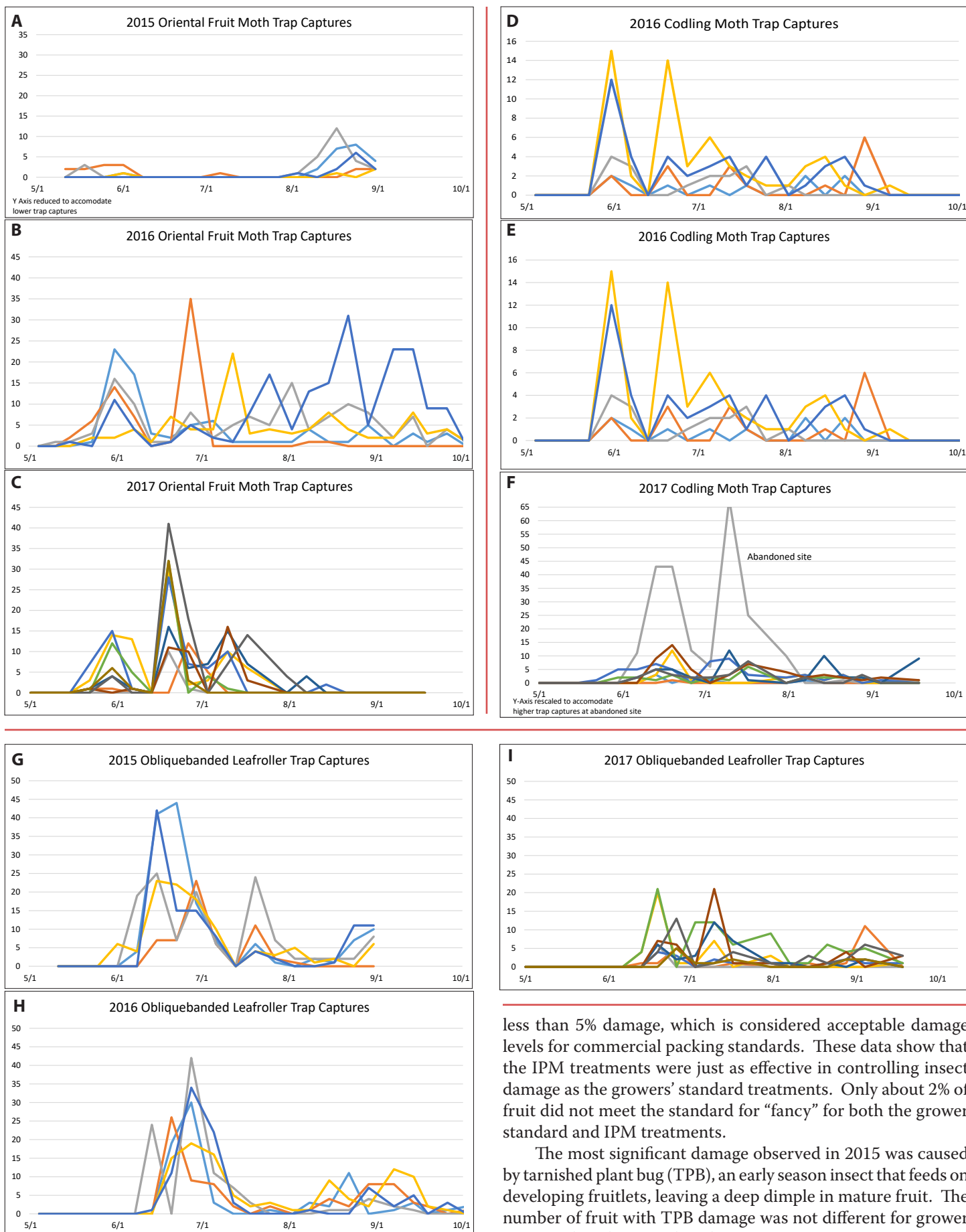


Figure 4. Trap captures of (A,B,C) oriental fruit moth, (D,E,F) codling moth, and (G,H,I) obliquebanded leafroller at monitoring sites in the Champlain Valley in 2015, 2016, and 2017.

less than 5% damage, which is considered acceptable damage levels for commercial packing standards. These data show that the IPM treatments were just as effective in controlling insect damage as the growers' standard treatments. Only about 2% of fruit did not meet the standard for "fancy" for both the grower standard and IPM treatments.

The most significant damage observed in 2015 was caused by tarnished plant bug (TPB), an early season insect that feeds on developing fruitlets, leaving a deep dimple in mature fruit. The number of fruit with TPB damage was not different for grower standard (2.4%) or IPM (2.3%) treatments. In both years, growers reported increasing pressure from TPB and other early season insects (in particular European apple sawfly and plum curculio).

Table 2. Average insect damage at harvest for 5 commercial sites in northeastern NY (% of 600 fruit sampled)

Damage Type*	2015		2016	
	Control (%)	IPM (%)	Control (%)	IPM (%)
Early OBLR	0.1	0.2	0.1	0.1
Late OBLR	0.1	0.4	0.1	0.4
AM	0.0	0.0	0.4	0.8
PC	0.5	0.7	1.5	1.0
TPB	2.4	2.3	1.0	0.9
RAA	0.0	0.0	0.0	0.0
SJS	0.1	0.0	0.0	0.0
EAS	0.0	0.2	0.3	0.2
SB	0.5	0.0	0.0	0.0
Scab	0.2	0.2	NA	NA

*OBLR=obliquebanded leafroller, AM=apple maggot, PC=plum curculio, TPB=tarnished plant bug, RAA=rosy apple aphid, SJS=San Jose scale, EAS=European apple sawfly, SB=stink bug

Table 3. Average fruit grade at harvest at 5 commercial sites in northeastern NY (% of 600 fruit sampled)

Packing Grade	2015		2016	
	Control	IPM	Control	IPM
Clean	96.3	96.0	100	96.4
Fancy	1.9	1.8	0.6	0.2
#1	1.6	1.9	1.5	2.3
Cull	0.3	0.4	1.4	1.1

*Note: values percentages do not add up to 100 for each column because they are an average of the percent damage in individual blocks

Considerable discussion was held with individual growers and industry members about the need for a “pink” spray, depending on individual years.

One major difference between our IPM recommendations and some growers’ standard treatments is that our IPM program omitted the traditional “pink insecticide spray.” Our results showed that the omission of the pink spray did not result in more early season fruit damage, but additional studies should be done in the future to validate these results. One grower reported more OBLR damage in the IPM fruit at harvest due to a delayed summer insecticide application, but this was not reflected in our fruit evaluation. This suggests that there may be different tolerance levels for summer worm injury among growers.

Another topic of considerable controversy in discussions with growers regarded waiting for the OBLR threshold (1 damaged fruit) to apply an insecticide for this insect. This is despite the fact that our results showed that no increased fruit damage resulted from following this IPM practice. This suggests that growers are uncomfortable about using traditional IPM practices of sampling and a treatment threshold for a pest such as OBLR that directly damages fruit. Fruit sampling programs do require some extra time and labor, and in larger scale operations, waiting for this threshold may not leave a large enough management window for

effective control, especially where there are insufficient resources to manage each block individually. In the future, more studies should be done to determine if sampling for fruit damage is feasible and if growers will accept this concept.

IPM Protocol: Carryover effect to 2016

In 3 of 5 sites, OBLR pressure (% terminals infested out of 600 rated) was higher in the Control than in the IPM block (Table 4). In only two locations was damage greater than 5%. On average, OBLR-infested terminals was at 2.4% in IPM blocks and 2.7% in Control blocks. These low infestation rates indicate that overwintering and early season OBLR activity was not impacted differently by treatments.

Table 4. Overwintering OBLR (Infested terminals) for 5 commercial sites in northeastern NY, evaluated May 2016. (% of 600)

Location	IPM	Control
1	1.17	0.33
2	1.00	2.50
3	2.67	10.67
4	6.83	4.17
5	0.17	0.67
Average	2.37	3.67

IPM Protocol: Targeted Insecticide Applications

Pesticide applications were much more targeted in the IPM blocks than in the Controls. In the IPM blocks, insecticides were *only* applied following model recommendations and when a pest population reached an action threshold, determined as the threshold at which economically significant damage would occur. In addition, applications targeted specific insects and life stages. However, pesticide applications in Control blocks were generally related to weather (covering after a rain) or calendar intervals (10–14-day periods). However, this is a gross over-generalization. Control blocks were managed very differently, due to variation between farms in pest management philosophy, comfort with the web-based tools, familiarity with newer chemistries, and the consultants and industry members supplying information to them.

Despite this variation, overall, growers made between 1 and 5 fewer insecticide applications in the IPM blocks than the grower standard blocks during the 2015 season. Typically this was because the IPM protocol eliminated an insecticide application at “pink” and reduced the number of mid-summer insecticide applications targeting OBLR and AM. Because of this, despite increased resources required to train workers in the IPM protocol, and time spent checking traps and scouting, growers likely saved a significant amount of money by using the IPM protocol.

An example of the spray program at a representative site in the Champlain Valley is shown in Figure 5, juxtaposing the IPM protocol and the Control. Key differences of note in the IPM protocol were: 1) dormant oil application at bud swell, 2) the “pink spray” was omitted, 3) summer insecticide applications were made exclusively when models recommended them, and 4) mite control was unnecessary in the summer, despite historically heavy mite pressure in both the Control and IPM blocks.

Outreach efforts

- 1) **Weekly scouting of orchards informed grower alerts.** In addition to informing the research project reported above, weekly scouting performed at the 5 study sites was used

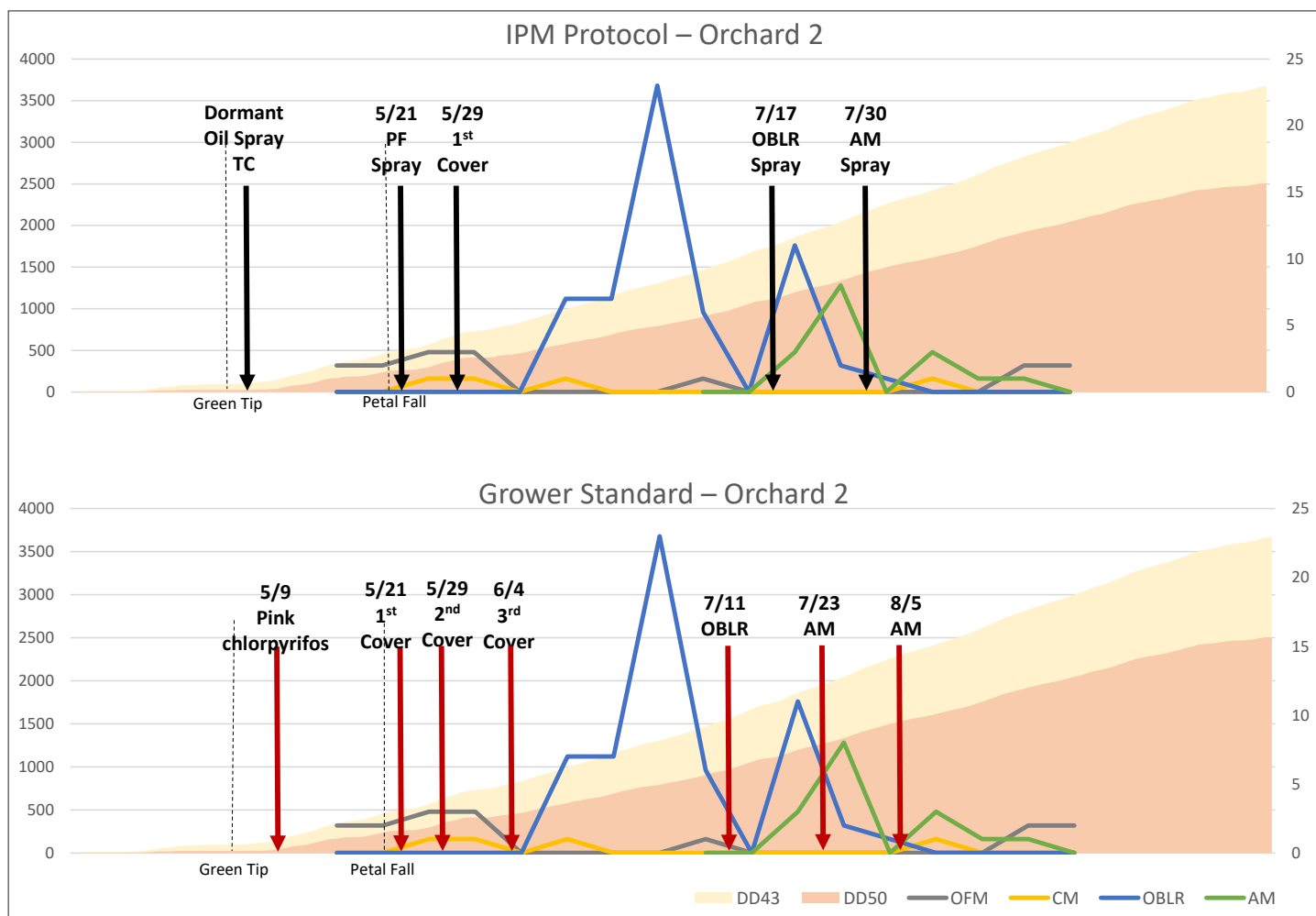


Figure 5. Comparison of spray programs in IPM and Control blocks of a representative orchard in 2015. The IPM treatment (top) included a dormant oil application prior to green tip, the pink spray was omitted, and subsequent sprays were guided by web-based tools. The Control treatment (bottom), representing a grower's standard management program, included the first spray at pink, and summer covers were made on a calendar and weather-dependent basis.

in grower outreach. Apple “e-alerts” are short emails developed in 2014 by the Eastern New York Commercial Horticulture Program Fruit Team (Dan Donahue, Anna Wallis) and produced approximately twice per week during the growing season, with the goal of providing an easy-to-digest, timely report on regional trends, management recommendations, and industry events. Weekly insect trap captures, field observations, and accompanying IPM recommendations were reported in these e-alerts in 2015, 2016, and 2017.

- 2) **Grower workshops provided hands-on training.** Several workshops were held in Northeastern NY to provide growers training on the apple IPM protocols and the resources available to assist in orchard pest management (Figure 6). Two Apple IPM Workshops were held in Peru and Ballston Spa in April 2015, attended by a total of 30 participants. Workshops were 5-hour, classroom-style programs, providing information on IPM theory, insect and disease pest biology and control, NEWA “Real Time IPM,” tree-row volume, and an example IPM plan. Presentations were given by Dr. Art Agnello, Dr. Julie Carroll, Dr. Kerik Cox, Dan Donahue, and Dr. Harvey Reissig. In March 2017, a one-day IPM training session focused on web-based pest management programs was held in Chazy, NY, attended by

21 participants from NY and VT.

- 3) **Response to fire blight epidemic in 2016.** A “perfect storm” of weather events in the spring of 2016 caused an epidemic of fire blight, an extremely destructive disease of apples, in the Champlain Valley. While it has previously been reported in this region, in most seasons conditions are not conducive to infection, and growers have extremely limited experience managing it. Because we were regularly visiting the 5 study sites in this work, we were well equipped to assist growers with management by:
 - Identifying the infections shortly after they occurred,
 - Tracking when, where, and how the disease was progressing in each of the locations and across the region,
 - Providing disease biology, activity, and management recommendations in e-alerts, and
 - Providing immediate, site-specific management recommendations

In addition, an emergency fire blight workshop was held in Peru during August 2016 following the epidemic in the Champlain Valley. Dr. Srdjan Aćimović, Plant Pathologist at the Hudson Valley Research Lab, presented information on cause of the epidemic, fire blight life history, and management strategies (Figure 7).



Figure 6. Cornell entomologist Dr. Art Agnello presents information on IPM theory and insect pest biology to growers at an Apple IPM Workshop in April 2015. The workshop also included presentations on disease management, NEWA, tree row volume, and a sample IPM plan, given by Dr. Kerik Cox, Dr. Julie Carroll, Dan Donahue, and Dr. Harvey Reissig. [Photo: A. Wallis]



Figure 7. Growers at an emergency fire blight workshop held in August 2016 following the epidemic in the Champlain Valley. Dr. Srdjan Acimović, Plant Pathologist at the Hudson Valley Research Lab, presents information on the cause of the epidemic, fire blight life history, and management strategies. [Photo: A. Wallis]

Conclusions

In general, insect populations and patterns in Northeastern NY followed patterns similar to other apple production regions in NY. This was somewhat surprising, as we expected lower populations and pressure due to the colder climate, shorter growing season, and geographic isolation of the region. In both 2015 and 2016, in the five sites included in this study, the IPM protocol we tested was found to be as effective as the grower standard in terms of fruit quality at harvest. The IPM protocol typically reduced the total number of sprays in the season and included more targeted pesticide applications, likely saving the growers time and money. However, the 'grower standard' is variable, and we found that many farmers were already following IPM recommendations in some capacity, if not entirely. There was great variability in insect pressure and flight patterns among sites. Continued monitoring will be necessary to detect regional and site-specific changes. Grower outreach was well received and should continue as it will provide growers with information on seasonal trends, regional variation, and recommendations for appropriate IPM management.

Acknowledgements

This work was partially funded by the Northern New York Agricultural Development Program. Thank you to the technicians, regional Extension personnel, and private consultants who assisted with and informed this work: Emelie Morton, David Wilfore, Annie Mills, Lindsey Pashow, Amy

Ivy, Laura McDermott, Jim Eve, and Eric Boire. Thanks also to the collaborating orchards involved in this project: Forrence Orchards, Northern Orchards, Chazy Orchards, Hart Apple Farm, and Banker Orchards.

References

- Acimović, S. 2017. (February 17). What is Climate Change and Can it Affect Apple Pests? Acimović Lab Blog. <https://blogs.cornell.edu/acimoviclab/2017/02/17/what-is-climate-change-and-can-it-affect-apple-pests/>
- Agnello, A. M., and Reissig, H. 2010. Development and validation of a "Real-Time" Apple IPM Website for New York. NY Fruit Q. 18(2): 25–28.
- Agnello, 2017a. (April 17). Upcoming Pest Events. Scaffolds Fruit J. 26(4): 8.
- Agnello, 2017b. (April 24). Upcoming Pest Events. Scaffolds Fruit J. 26(5): 5.
- Agnello, 2017b. (June 5). Upcoming Pest Events. Scaffolds Fruit J. 26(11): 4.
- APHIS. 2010. (August). Attack of the Invasive Species [Factsheet]. Retrieved from: https://www.aphis.usda.gov/publications/plant_health/content/printable_version/fs_attack_of_the_invasive_species.pdf
- Bebber, D. P., Ramotowski, M.A.T., and Gurr, S. J. 2013. Crop pests and pathogens move polewards in a warming world. Nat. Clim. Change 3: 985–988.
- Breth, D., DeMarree, A., Agnello, A., and Tee, E. 2010. NY Fruit Q. 18(4): 19–23.
- Jentsch, P. 2017. (March 30). Letter to EPA In Support of the Retention of Chlorpyrifos Registration and Use in Tree Fruit for Trunk Applications Against Invasive Boring Pests in New York State. Jentsch Lab Blog. Retrieved from: <https://blogs.cornell.edu/jentsch/in-support-of-the-retention-of-chlorpyrifos-registration-and-use-in-tree-fruit-for-trunk-applications-against-invasive-boring-pests-in-new-york-state/>
- Robinson, T., Hoying S., Miranda Sazo, M., DeMarree, A., and Dominguez, L. 2013. A Vision for Apple Orchard Systems of the Future. NY Fruit Q. 21(4): 11–16.
- Robinson, T., Fazio, G., and Aldwinckle, H. 2014. Characteristics of New Apple Rootstock from the Cornell-USDA Apple Rootstock Breeding Program. Compact Fruit Tree 47(3).

Anna Wallis is an Extension Associate with the Eastern NY Commercial Horticulture Program, CCE. **Arthur Agnello** is a research and extension professor in the Department of Entomology at Geneva who leads Cornell's extension program in tree fruit entomology. **Harvey Reissig** is a professor emeritus in the Department of Entomology at Geneva who specialized in arthropod management and led Cornell's Pest Management Education Program.





Columbia Tractor, Inc.

*Serving the Hudson Valley & Western New England
with these quality lines of tractors & equipment:*

— Case IH — Kubota — Bush Hog — Woods — Kinze —
— Unverferth — Brillion — Monosem — Unverferth —
— Ag-Tec Sprayers — Aerway Aerators — Husqvarna —
— Kawasaki Mule — Befco — Echo — Great Plains Drills —

Call us for Parts - Service - New & Used Tractors & Equipment

PO Box 660, 841 Route 9H, Claverack, NY 12513

Approx. 40 miles south of Albany, NY, in the Hudson Valley

Phone: 518-828-1781 • 800-352-3621 • Fax: 518-828-2173

Email: skinne@columbiatractor.com Web: www@columbiatractor.com

Specialized. Diverse. Innovative.

At Adams County Nursery we specialize in commercial fruit tree nursery stock for a diverse, eastern market using the latest in technology and innovation.



Adams County Nursery, Inc. • (800) 377-3106 • (717) 677-4124 fax
www.acnursery.com • email: acn@acnursery.com

Wild apple species as a source of fire blight resistance for sustainable productivity of apple orchards

Awais Khan¹ and Thomas Chao²

¹Plant Pathology and Plant-Microbe Biology Section, Cornell University, New York State Agricultural Experiment Station, Geneva, NY

²USDA-ARS Plant Genetic Resources Unit, New York State Agricultural Experiment Station, Geneva, NY

This research was partially supported by the New York Apple Research and Development Program

The susceptibility of commercial apple scion varieties and rootstocks to pathogens and insects greatly reduces orchard productivity and fruit quality. Since its first report almost 200 years ago in a pear orchard in the Hudson Valley, NY, fire blight has been a major threat to apple and pear production in New York State (Norelli et al. 2003). The causative

bacteria (*Erwinia amylovora*) can enter via natural stomatal and blossom openings, physical injuries/wounds caused by hail storms, farm equipment, and rain splashes, making their entry difficult to stop. Insects and bees can spread the bacteria during bloom time from infected trees to healthy trees, as can contaminated tools; for example, pruners and shears. Rain after an infection event washes bacteria down and can spread it to rootstocks, which also can ultimately lead to the death of the tree. Fire blight causes economic losses exceeding \$100 million each year in the US through blossom, shoot, or rootstock blight alone. A major epidemic of fire blight in 2000 in Michigan led to the loss of more than 600 acres of orchards, or over \$42 million loss for the growers (Norelli et al. 2003). Chemicals can be used to prevent fire blight infection, but once the pathogen is inside the plant tissue, there is no effective chemical treatment. The use of chemical control methods with antibiotics has also led to the emergence of antibiotic-resistant bacteria strains that could cause a sudden fire blight epidemic (Cox et al. 2012). In addition, both management of fire blight and use of preventive chemical sprays contribute significantly to production costs. The actual cost incurred by disease damage and management is difficult to estimate, because of the recurring cost of sprays, pruning of infected parts, waste of fruit due to decreased quality, and the multi-year impact due to loss of productive trees.

Fire blight control via chemicals and pruning of infected parts is difficult and costly; therefore, developing resistant apple cultivars is considered to be the best option for fire blight management (Luby et al. 2002). Apple cultivars with improved

disease resistance are needed to meet market demands and for optimal performance in the face of not only the challenge of existing pathogens, but also for newly emerging diseases, the changing population of the pathogen strains, as well as abiotic stresses. Strains of *Erwinia amylovora* have shown high genetic variability and rapid changes in the genome in response to the use of antibiotics. Mutated strains of fire blight could escape sprays and infect previously resistant apple cultivars (Smits et al. 2014). However, existing resistance genes in the natural apple (*Malus*) germplasm will allow breeding of new cultivars with enhanced disease resistance, as long as the genes are clearly identified.

Approximately 28 regions in the apple genome have been identified as sources of major or minor resistance to fire blight (Khan et al. 2012). The five major regions were identified on chromosome 3 in *Malus robusta* 5, chromosome 7 in cv. Fiesta, chromosome 10 in 'Evereste', and chromosome 12 in *Malus fusca* and *Malus x arnoldiana* (Khan et al. 2007; Parravicini et al. 2011; Fahrentrapp et al. 2013; Emeriewen et al. 2014, 2017). All of these major resistance genomic regions originate from wild apple species except in cv. Fiesta. A DNA-based marker test of the cv. Fiesta pedigree showed that it inherited this resistance from apple cv. Cox's Orange Pippin and that other cultivars that share a pedigree with the cv. Fiesta also carries this resistance region (Khan et al. 2007). Most of these regions have a major gene underlying the resistance and they are fire blight bacterial strain-specific. The major fire blight resistance gene on chromosome 3 from *Malus robusta* 5 has been transformed by a European group into the fire blight-susceptible cv. Gala, which then showed significantly lower infection from artificial inoculations with *E. amylovora* (Broggini et al. 2014). There is great potential for tapping into natural resistance in wild apple species and incorporating it into susceptible but commercially important and consumer favorite cultivars using conventional or genome-assisted breeding or transgenic approaches, where appropriate and accepted. In an apple breeding program, DNA markers linked to the resistance genes are used to select apple seedlings from a cross between susceptible and resistant parents.

High genetic variability in *E. amylovora* and its capacity to rapidly mutate in response to high selection pressure can allow it to overcome cultivar resistance. For example, a highly aggressive *E. amylovora* strain can overcome major resistance from *Malus robusta* 5 (Peil et al. 2011). Additionally, even a minor variation in the genome of a host plant can cause a major change in gene function, either through complete loss of resistance or altering the resistance spectrum. Disease severity of the host depends



Orchard Hedgers



Chain Top Bin Trailer

Building specialized orchard equipment to meet your unique requirements!

LaGasse Works, Inc.

(888) 946-9202
works@lagasseworks.com

**5 Old Route 31
 Lyons, NY 14489**



Refrigerated and Ventilated Cooling Systems for Fruit and Vegetable Storages

- **COMMERCIAL REFRIGERATION**
- **DESIGN, SALES AND SERVICE**
- **SERVING AGRICULTURE FOR 70 YEARS**

Free Consultation and Quote
Call Mike Mager at 585-343-2678

ARCTIC

REFRIGERATION CO. OF BATAVIA
 26 Cedar Street, Batavia, NY 14020
www.arcticrefrigeration.com

**See us at
 the Empire
 State Show!
 Jan. 16-18
 Booth #70**

One Bushel Crates



Well built and reliable, these boxes will protect your produce. In bulk, \$8.50 each

Hamlin Sawmill
 1873 Redman Rd. Hamlin, NY 14464
 585-964-3561
art@rochester.rr.com
www.OneBushelCrate.com

on the interaction of its resistance genes and aggressiveness of the corresponding pathogen strains. At any one time, several *E. amylovora* strains exist in an apple orchard with varying aggressiveness, resulting in different levels of fire blight infection (Norelli et al. 1986). Therefore, it is important to test the response of host plants to the multiple bacteria strains commonly found in local orchards. Exposing *Malus* germplasm to multiple bacteria strains will not only test the stability and effectiveness of resistance genes to a large number of bacterial strains, but can lead to the identification of novel resistance genes.

The USDA-ARS National Plant Germplasm System (NPGS) *Malus* collection at the Plant Genetic Resources Unit (PGRU), Geneva, NY represents great diversity for horticultural traits, fruit quality, and disease resistance. This is the world's most diverse *Malus* collection, holding 6,778 *Malus* accessions from 52 species, of which 5,196 accessions are trees in the field and 1,582 accessions are seed lots from Asia, Europe, and North America. These accessions were obtained from research institutions, breeding programs, and genebanks around the world, or collected through expeditions in Central Asia between 1986 and 1996 by Phil Forsline (PGRU, Geneva, NY) and Herb Aldwinckle (Cornell University, Geneva, NY). A large component of this collection is old and new cultivars from *M. domestica* and hybrids with different wild *Malus* species. A significant part of the collection is maintained in the field at Geneva, including a *Malus* core collection maintained on B.9 rootstock, a permanent collection on EMLA 7 rootstock, *M. sieversii* seedlings from Kazakhstan, and wild *Malus* species seedlings from Armenia, China, Georgia, Russia, and Turkey. This germplasm is routinely shared with the research and breeding community in the US and internationally to assess disease resistance, fruit quality, and horticultural traits and as a potential source of genes for use in genetic improvement of scion cultivars and rootstocks of apple for resistance to economically important diseases. This collection has primarily been evaluated for preliminary descriptors and to assess genetic diversity in general. Part of this collection, at different times, has also been evaluated for fire blight and apple scab resistance by plant pathologists at Cornell University, the PGRU staff at Geneva, and other research groups in the US, Canada, and Europe (Volk et al. 2015; Harshman et al. 2017). Although the collection contains great naturally occurring and functionally diverse disease resistance, the lack of detailed characterization and availability of this data limits their utilization. With the recent advances in genome sequencing and disease phenotyping, the collection could be comprehensively characterized at DNA levels, and for specific diseases.

Materials and Methods

Field observation data for shoot fire blight for 2,362 *Malus* accessions from 52 species and blossom blight of 694 *Malus* accessions from 41 species, characterized by PGRU, were downloaded from the Germplasm Resources Information Network (GRIN-Global database). We also accessed fire blight inoculation data from a two-year (2011 and 2012) greenhouse experiment using a subset of the *Malus* collection. Artificial inoculation was done in the greenhouse on young *Malus* plants grafted onto B.9 using *E. amylovora* strain Ea273 (Khan et al. 2013). Field observation data was collected as qualitative scores; 1 (very resistant) and 5 (very susceptible) as described by Postman et al. (2010, Table 4) and <http://www.ars-grin.gov/>

[npgs/descriptors/apple](#). Data in the greenhouse was collected as average percentage of fire blight necrosis length (PLL). In order to compare datasets, we used data for accessions that were either resistant (below 10 PLL) or susceptible (above 35 PLL) in the greenhouse experiment, and that were also present in the field study.

Results and discussion

The blossom fire blight data downloaded from USDA GRIN-Global was for 694 accessions from 41 species. Only 638 accessions from 14 species had more than 5 accessions/species; i.e., 27 species had less than four accessions per species. *M. prunifolia*, *M. baccata*, *M. hybrid*, and *M. domestica* each had blossom blight data for more than 11 accessions. Our analysis showed highly resistant scores (1-2) for more than 65% of accessions from *M. angustifolia*, *M. ioensis*, *M. spp*, *M. sieversii*, *M. toringo*, and *M. coronaria*. *Malus sieversii* from Central Asia, the main progenitor of modern day apples, had 33% of accessions highly susceptible to blossom blight. European crab apple (*M. sylvestris*), which has also contributed significantly to the genome of domesticated apples, had 80% of accessions that were highly susceptible to blossom fire blight. Domesticated apples had 21% of the accessions rated as resistant and approximately 60% as highly susceptible (4-5).

Shoot fire blight data was available for 2,362 apple accessions from 52 species. There were 2,318 accessions from 33 species with at least 5 accessions per species. *M. prunifolia*, *M. ioensis*, *M. fusca*, *M. baccata*, *M. coronaria*, *M. sieversii*, *M. hybrid*, and *M. domestica* each had more than 35 accessions with shoot fire blight data. More than 65% of accessions from *M. ombrophila*, *M. prattii*, *M. fusca*, *M. spp.*, *M. sieversii*, *M. halliana*, *M. coronaria*, *M. x hartwigii*, and *M. x asiatica* had highly resistant scores (1-2) for shoot blight. From cultivated apples (*M. domestica*), 18% of accessions were resistant (1-2) and almost 75% accessions were highly susceptible (4-5) to shoot blight. *Malus sieversii* had 71% and 25% of accessions in resistant and susceptible categories, respectively, while European crab apple had 33% and 66% accessions rated as resistant and susceptible, respectively.

There are 26 species with shoot fire blight data for at least 10 accessions. Of these, we found approximately 31% and 11% potential shoot blight and blossom blight-resistant accessions (score 1-2), respectively, which could be a valuable resource for identifying new resistance genes with potential use in apple breeding and biotechnology (Figure 1). Field observation data can have false positives and negatives due to the sporadic nature of fire blight and random distribution of inoculum and strains in the field. Comparison with greenhouse fire blight inoculation results using a subset of this collection showed a consistent ranking for several overlapping accessions between the two data sets (Figure 2), although there are inconsistencies as well. These discrepancies could be from environmental factors that can influence the interaction between the host and pathogen in the field, escape of the host plant from infection, especially for accessions that were identified as highly resistant (score of 1), or strain and host specificity. For example, accessions that are scored 5 (very susceptible) in the field, but show very low infection to Ea273 strain in the greenhouse experiment, could be susceptible to other, highly virulent strains, present in the field. Also, the ranking of wild *Malus* species based on average

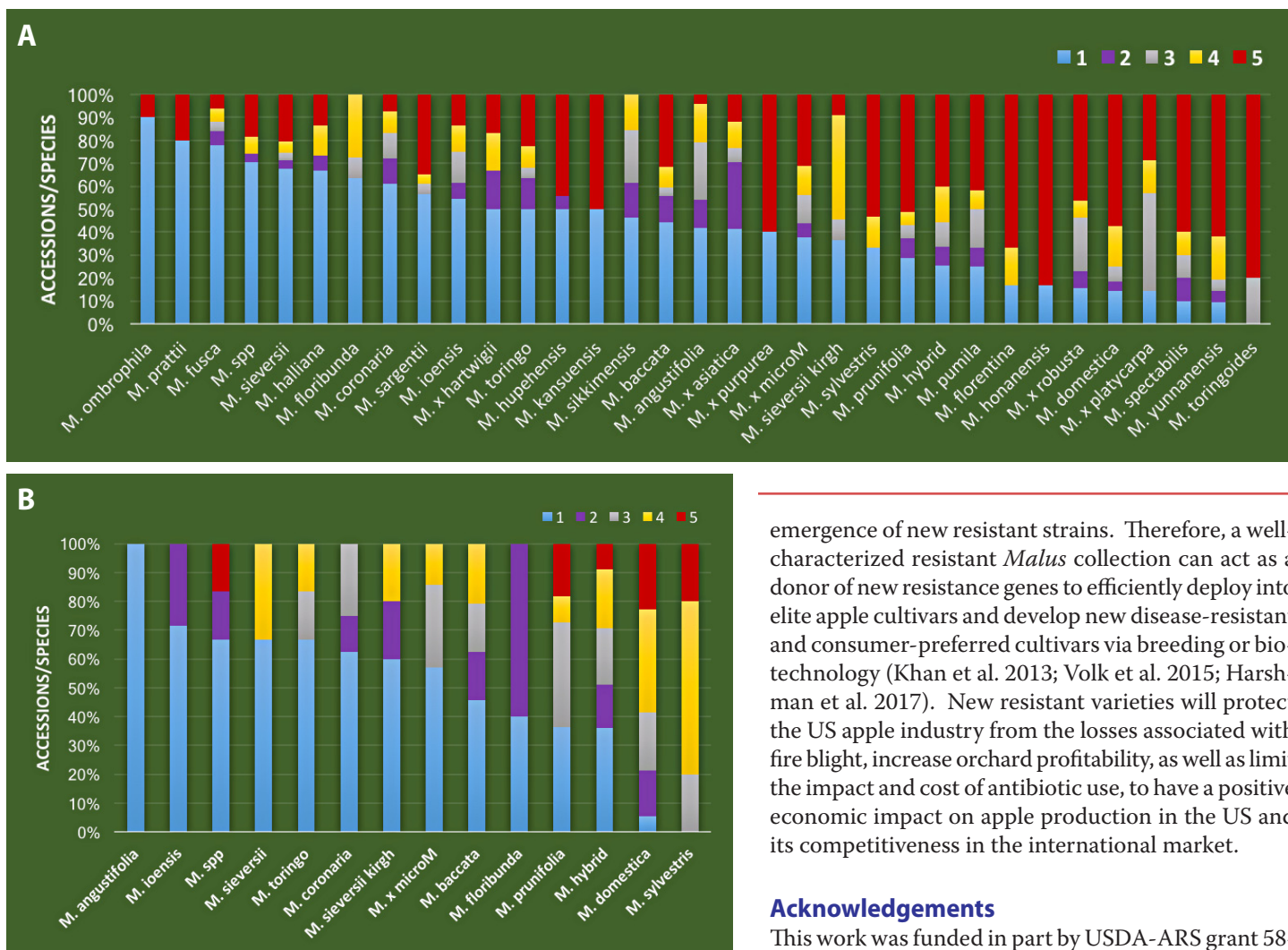


Figure 1. a) Shoot blight (FBSH/NAT) and b) blossom (FBBL/NAT) fire blight/species for *Malus* collection available at USDA-ARS-NPGS GRIN-Global database. Data was collected on a 1-5 scale (resistant-susceptible) in the orchard. Data is shown for 26 species with at least 10 accessions each.

rating of accessions per species in field observation data is consistent with other controlled studies (Figure 1). Therefore, this data can provide a basis for confirmation of resistance through detailed and systematic characterization, selection of *Malus* accessions for identifying novel resistance genes, and as disease resistance donors for future apple breeding and research. Accessions of promising species such as *M. sieversii*, *M. fusca*, and *M. toringo* should be further evaluated for shoot and blossom fire blight, especially for bacterial strains prevalent in New York.

In addition to fresh fruit, cider, and juices, an increase in apple value-added products, pick-your-own orchards, increased concerns about human health, and rising incomes, demand development of new varieties with market-specific attributes. However, improved disease resistance of scion cultivars and rootstocks is the foundation for all these market-specific uses, including organic orchard production. Emergence of new diseases and new pathogen strains is a common problem across the entire cropping system, but is more pronounced in high-density apple orchards. The majority of the top ten commercial scion cultivars and rootstocks produced and sold in the US – e.g., Gala, Red Delicious, Granny Smith, Fuji, Golden Delicious, Honeycrisp, McIntosh, Rome, Cripps Pink/Pink Lady®, Empire, and M.9 – are all susceptible to bacterial, fungal, soil-borne, and post-harvest diseases. Application of antibiotics and fungicides significantly increases production costs, with environmental and health concerns, and leads to

emergence of new resistant strains. Therefore, a well-characterized resistant *Malus* collection can act as a donor of new resistance genes to efficiently deploy into elite apple cultivars and develop new disease-resistant and consumer-preferred cultivars via breeding or biotechnology (Khan et al. 2013; Volk et al. 2015; Harshman et al. 2017). New resistant varieties will protect the US apple industry from the losses associated with fire blight, increase orchard profitability, as well as limit the impact and cost of antibiotic use, to have a positive economic impact on apple production in the US and its competitiveness in the international market.

Acknowledgements

This work was funded in part by USDA-ARS grant 58-8080-7-006, developing apple germplasm donor stock for novel strain-specific and broad-spectrum alleles and genes for fire blight genetic research and resistance breeding. This work was also supported in part by the New York Apple Research and Development Program (ARDP). Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the United States Department of Agriculture (USDA).

References

- Broggini, G.A.L., Wöhner, T., Fahrentrapp, J., Kost, T. D., Flachowsky, H., Peil, A., Hanke, M.-V., Richter, K., Patocchi, A., and Gessler, C. 2014. Engineering fire blight resistance into the apple cultivar ‘Gala’ using the FB_MR5 CC-NBS-LRR resistance gene of *Malus x robusta* 5. *Plant Biotechnol. J.* 12(6): 728–733.
- Cox, K., Aldwinckle, H., Carroll, J., and Burr, T. 2012. Statewide survey for streptomycin-resistant fire blight in orchards. New York State IPM Prog. Grants Report. <http://hdl.handle.net/1813/42504>
- Emeriewen, O. F., Peil, A., Richter, K., Zini, E., Hanke, M.-V., and Malnoy, M. 2017. Fire blight resistance of *Malus x arnoldiana* is controlled by a quantitative trait locus located at the distal end of linkage group 12. *Eur. J. Plant Pathol.* 148(4): 1011–1018.

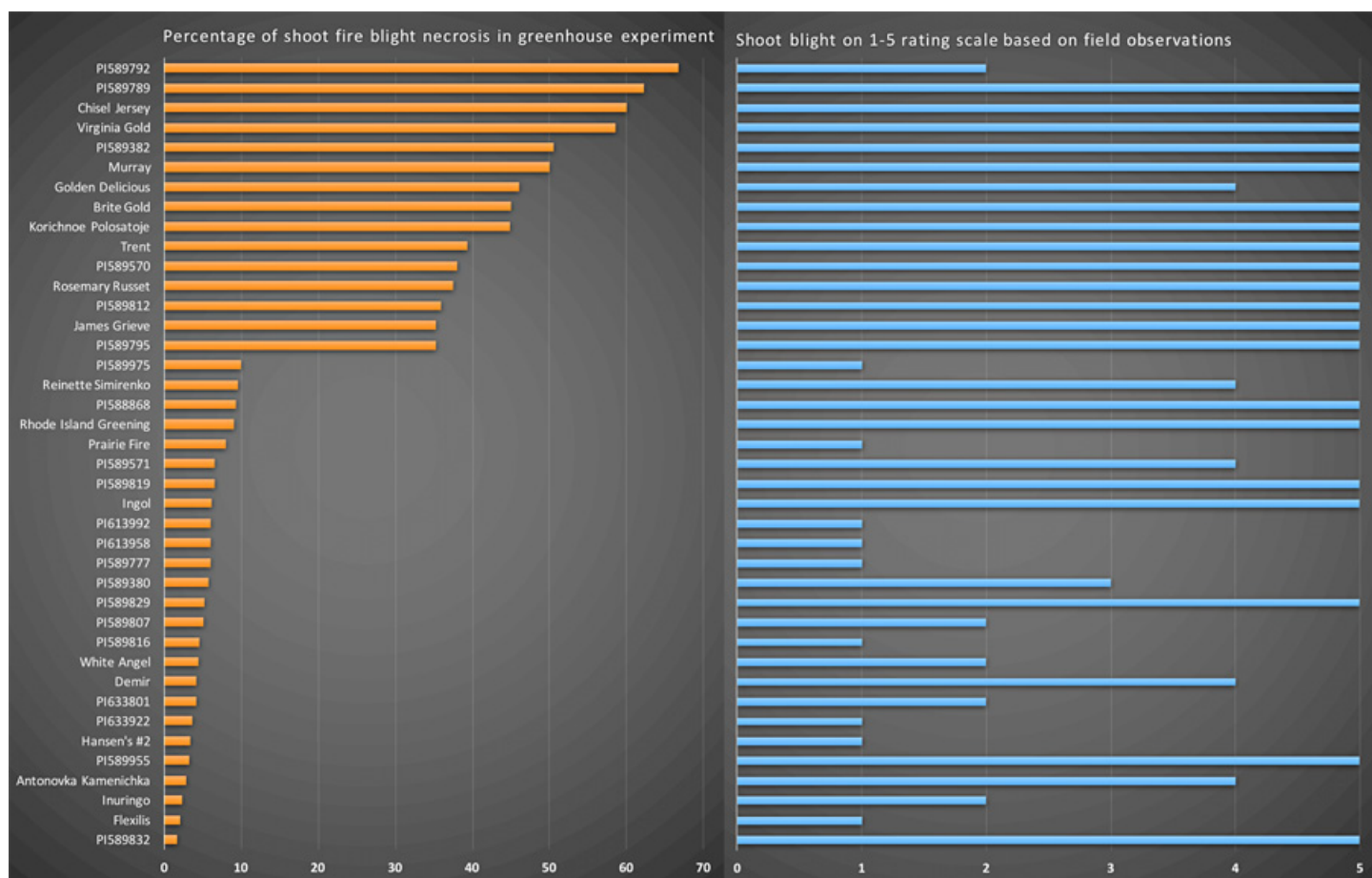


Figure 2. Fire blight inoculation results from natural shoot blight in the field (observational data) and average percentage of fire blight necrosis length (PLL) from two-year (2011 and 2012) artificial inoculation data in the greenhouse with *E. amylovora* strain Ea273 (Khan et al. 2013). Data is shown for accessions that were either resistant (below 10 PLL) or susceptible (above 35 PLL) in the greenhouse experiment, and that were also present in the field study. Natural blight scores are 1 (very resistant) and 5 (very susceptible) as described Postman et al. (2010, Table 4) and <http://www.ars-grin.gov/npgs/descriptors/apple>.

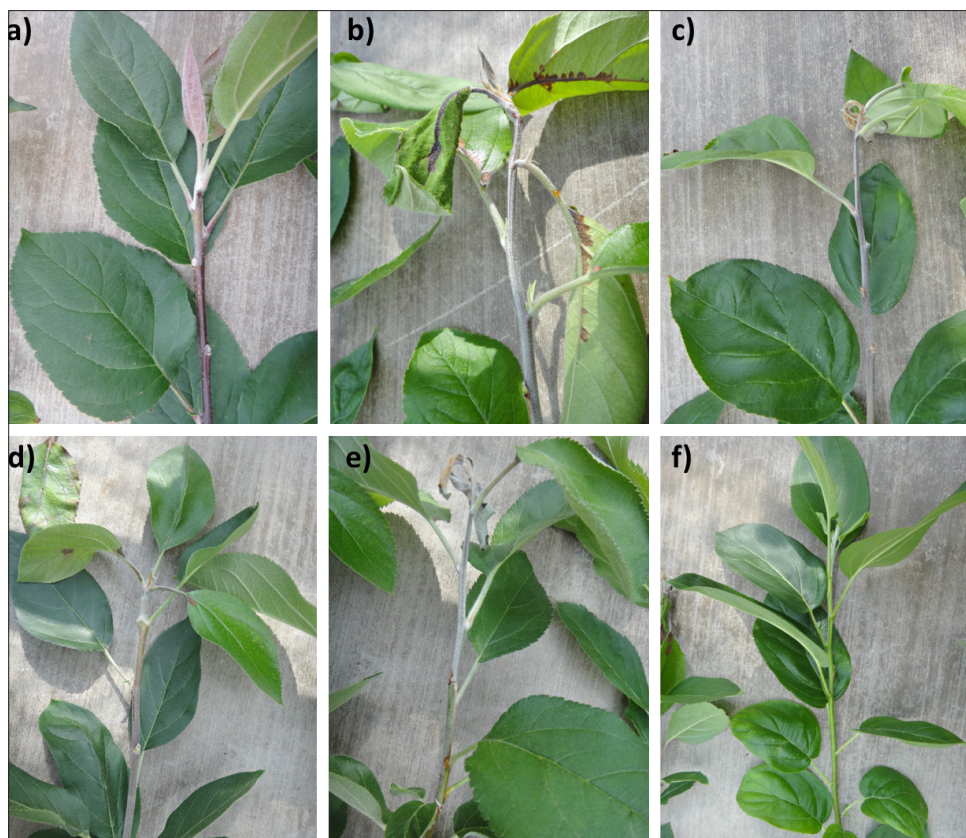


Figure 3. Shoots of young apple accessions from a subset of the apple collection at PGRU grafted onto B.9 rootstock and inoculated (using a hypodermic needle) in the greenhouse with a bacterial culture of *Erwinia amylovora* strain Ea273 at University of Illinois, Urbana-Champaign. Note bacterial oozing, wilting, and typical shepherd's crook symptoms observed on susceptible shoots and regeneration of new tissue on resistant shoots. a) Resistance response: point of inoculation but no progress in disease, b) highly susceptible with bacterial ooze and necrosis of leaves and shoot, c) susceptible with shepherd's hook and dead stem tissue, d) moderately susceptible, with slow progress, e) susceptible with shepherd's hook and dead stem tissue, f) highly resistant.

- Emeriewen, O., Richter, K., Kilian, A., Zini, E., Hanke, M.-V., Malnoy, M., and Peil, A. 2014. Identification of a major quantitative trait locus for resistance to fire blight in the wild apple species *Malus fusca*. *Mol. Breed.* 34(2): 407–419.
- Fahrentz, J., Broggini, G.A.L., Kellerhals, M., Peil, A., Richter, K., Zini, E., and Gessler, C. 2013. A candidate gene for fire blight resistance in *Malus× robusta* 5 is coding for a CC–NBS–LRR. *Tree Genet. Genomes* 9(1): 237–251.
- Harshman, J. M., Evans, K. M., Allen, H., Potts, R., Flamenco, J., Aldwinckle, H. S., Wisniewski, M. E., and Norelli, J. L. 2017. Fire blight resistance in wild accessions of *Malus sieversii*. *Plant Dis.* 101(10): 1738–1745.
- Khan, M. A., Zhao, Y. F., and Korban, S. S. 2013. Identification of genetic loci associated with fire blight resistance in *Malus* through combined use of QTL and association mapping. *Physiol. Plant.* 148(3): 344–353.
- Khan, M. A., Zhao, Y. F., and Korban, S. S. 2012. Molecular mechanisms of pathogenesis and resistance to the bacterial pathogen *Erwinia amylovora*, causal agent of fire blight disease in Rosaceae. *Plant Mol. Biol. Rep.* 30(2): 247–260.
- Khan, M. A., Durel, C.-E., Duffy, B., Drouet, D., Kellerhals, M., Gessler, C., and Patocchi, A. 2007. Development of molecular markers linked to the ‘Fiesta’ linkage group 7 major QTL for fire blight resistance and their application for marker-assisted selection. *Genome* 50(6): 568–577.
- Kost, T. D., Gessler, C., Jansch, M., Flachowsky, H., Patocchi, A., and Broggini, G.A.L. 2015. Development of the first cisgenic apple with increased resistance to fire blight.” *PloS one* 10(12): e0143980.
- Luby, J. J., Alspach, P. A., Bus, V.G.M., and Oraguzie, N. C. 2002. Field resistance to fire blight in a diverse apple (*Malus* sp.) germplasm collection. *J. Am. Soc. Hort. Sci.* 127(2): 245–253.
- Malnoy, M., Martens, S., Norelli, J. L., Barny, M.-A., Sundin, G. W., Smits, T.H.M., and Duffy, B. 2012. Fire blight: applied genomic insights of the pathogen and host. *Annu. Rev. Phytopathol.* 50: 475–494.
- Norelli, J. L., Aldwinckle, H. S., and Beer, S. V. 1986. Differential susceptibility of *Malus* spp. cultivars Robusta 5, Novole, and Ottawa 523 to *Erwinia amylovora*. *Plant Dis.* 70(11): 1017–1019.
- Norelli, J. L., Jones, A. L., and Aldwinckle, H. S. 2003. Fire blight management in the twenty-first century: using new technologies that enhance host resistance in apple. *Plant Dis.* 87(7): 756–765.
- Parravicini, G., Gessler, C., Denance, C., Lasserre-Zuber, P., Vergne, E., Brisset, M.-N., Patocchi, A., Durel, C.-E., and Broggini, G.A.L. 2011. Identification of serine/threonine kinase and nucleotide-binding site–leucine-rich repeat (NBS-LRR) genes in the fire blight resistance quantitative trait locus of apple cultivar ‘Evereste’. *Mol. Plant Pathol.* 12(5): 493–505.
- Peil, A., Flachowsky, H., Hanke, M.-V., Richter, K. and Rode, J. 2010. Inoculation of *Malus× robusta* 5 progeny with a strain breaking resistance to fire blight reveals a minor QTL on LG5. In: XII International Workshop on Fire Blight 896, pp. 357–362.
- Postman, J., Volk, G., and Aldwinckle, H. 2010. Standardized plant disease evaluations will enhance resistance gene discovery. *HortScience* 45(9): 1317–1320.
- Smits, T.H.M., Guerrero-Prieto, V. M., Hernández-Escarcega, G., Blom, J., Goesmann, A., Rezzonico, F., Duffy, B., and Stockwell, V. O. 2014. Whole-genome sequencing of *Erwinia amylovora* strains from Mexico detects single nucleotide polymorphisms in rpsL conferring streptomycin resistance and in the avrRpt2 effector altering host interactions. *Genome Announc.* 2(1): e01229–13.
- Volk, G. M., Chao, C. T., Norelli, J., Brown S. K., Fazio, G., Peace, C., McFerson, J., Zhong, G.-Y., and Bretting, P. 2015. The vulnerability of US apple (*Malus*) genetic resources. *Genet. Resour. Crop Evol.* 62(5): 765–794.

Awais Khan is an Associate Professor of Plant Pathology, at Cornell’s New York State Agricultural Experiment Station in Geneva, where his research and extension program focuses on mechanisms of disease resistance and disease management through host resistance in fruit crops. **C. Thomas Chao** is a horticulturist and curator for the *Malus* germplasm collection at USDA-ARS Plant Genetic Resources Unit, Geneva, NY.

800.424.2765 • www.summittreesales.com •  Like us on Facebook



SUMMIT TREE SALES

REPRESENTING THE COUNTRY’S FINEST NURSERIES

It’s our mission to help you find the trees you need.
Make Summit Tree Sales your first call!

800.424.2765

Book future grower contracts NOW!

Now offering **yieldMAX** picking buckets.



Jan Melvin



Katie Schuld



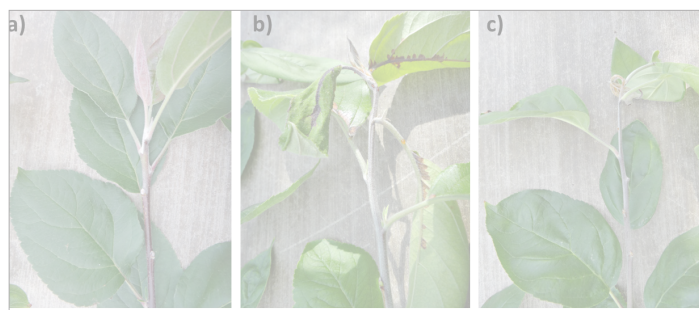
Dawn Melvin



Matthew Schuld

THINK LONG TERM

THE EFFORT YOU MAKE TODAY WILL REWARD YOU IN THE FUTURE.





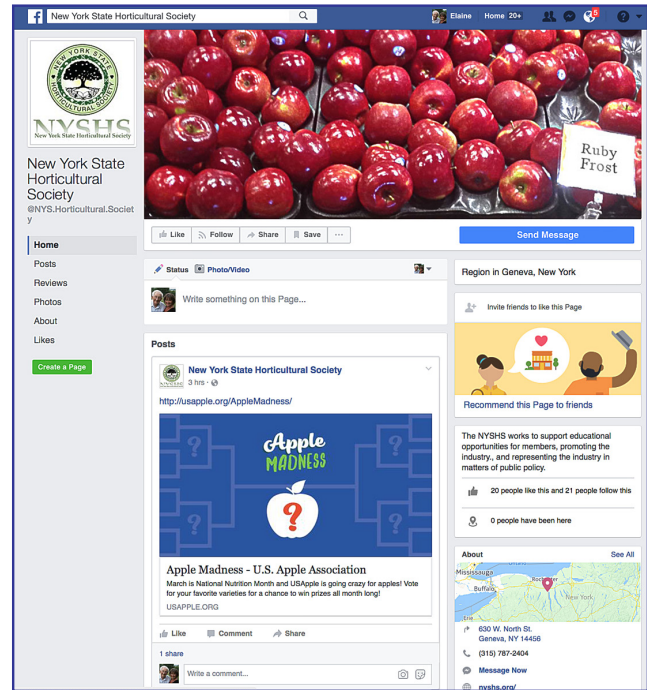
The NYSHS now has a Facebook page.

Get updates, plus links
to other agricultural
organizations!



Follow Us On Facebook:

www.facebook.com/NYSHorticulturalSociety



LOVES farm-fresh produce, tax,
yoga, hiking and planning.



*Our associates love what they do. How about you?
Send us your selfie at FarmCreditEast.com/WeAreYou*

The word “taxes” may not bring a smile to most people’s face, but Jamie Johnson isn’t most people — she’s a tax consultant for Farm Credit East. And as a consultant, she loves helping our clients maximize their deductions, stay up-to-date with current tax law, and ensure that they never pay more than they should. That means planning well before it’s time to file, forecasting your end-of-year liabilities and developing strategies to keep your tax burden to an appropriate minimum.

Preparing taxes may not be your idea of a good time, but with a Farm Credit East tax consultant in your corner, you can be sure that you’ve put in place the most beneficial tax arrangement for your business — because WE ARE YOU.



FARM CREDIT EAST

800.562.2235

FarmCreditEast.com/TaxPlanning

Empire State Producers Expo

EXPO



January 16-18, 2018

SRC Arena & Event Center, Syracuse, New York

Becker Forum: Jan 16, 2017 - Holiday Inn, Liverpool

GROWING FOR THE HEALTH OF NEW YORK



This show combines the major fruit, flower, vegetable, and direct marketing associations of New York State in order to provide a comprehensive trade show and educational conference for the fruit and vegetable growers of this state, as well as the surrounding states and Eastern Canada.

For more information:

<https://nysvga.org/expo/information/>



Red-juiced apple cultivars for Great Lakes production

Steve van Nocker and Chris Gottschalk

Department of Horticulture, Michigan State University, East Lansing, MI

Anthocyanins, beauty, and the color of apples

The saying that “beauty is only skin deep” could easily apply to the typical apple, which produces the red pigments only in the epidermal cell layers of the peel. These pigments

“Many ornamental apple cultivars have red flesh and produce red juice, offering potential for new apple-based food and health products. In this article we summarize our efforts to identify, select, and breed red-juiced apple cultivars for future production in the Great Lakes states.”

– called anthocyanins – comprise a large and heterogeneous group of natural compounds. Depending on the exact structure of the particular anthocyanin molecule, and the pH of its environ-

ment, anthocyanins can range in color from red to purple to blue. Anthocyanins serve a variety of biological roles. In the skin of fruit such as apple or blueberry, anthocyanins act as visual attractants for animals that would eat the fruit and disperse the seeds in the dung. In flowers, anthocyanins help to attract pollinators. Anthocyanins may also be produced by plants as photoprotectants – a natural sunscreen – especially in times of stress.

Naturally, humans are also attracted to red fruit, and this has driven the breeding and selection of apple cultivars with enhanced skin color – the so-called color sports. For consumers, skin color is an important assessment factor for fruit quality. In addition, anthocyanins are included in a broader class of natural compounds termed flavonoids, which are commonly believed to positively impact human health because they are strong antioxidants. These economic factors have driven decades of research on the genetic, environmental, and production factors contributing to anthocyanin content in the fruit.

Red-fleshed apples: “Beauty is more than skin deep!”

Interestingly, many cultivars of apple produce anthocyanins not only in the skin, but in many other parts of the plant. Such cultivars are easily recognizable by their purple foliage and red or purple flowers (Fig 1A). In most of these cultivars, the fruit cortex (flesh) is pink or light red, and these have been referred to as “red-fleshed” cultivars. Our research at MSU suggests that nearly all of these cultivars are descended from a single variety, ‘Niedwetskyana’ (Fig 1B), believed to originate in central Asia. Because of the ornamental value of the foliage and flower color, this trait from ‘Niedwetskyana’ has been exploited in the development of many ornamental crabapple cultivars. As these became widely planted in populated areas, natural cross-pollination with other cultivars and wild apples further increased the genetic diversity (van Nocker et al. 2007).

During the early 20th century, breeders such as Niels Ebbesen Hansen and Albert Etter began to develop red-fleshed culinary cultivars. Most of this work utilized genetic material that was

distinct from ‘Niedwetskyana’. In these apples, anthocyanins were produced at high levels in the fruit flesh, but not in other parts of the plant, such that plants showed typical green foliage and white flowers. Their early work produced some varieties still grown today, such as the light-skinned ‘Pink Pearl’ (Fig 1C). More recently, increased understanding of the genetics that underlie the red flesh trait has reinvigorated breeding efforts. New Zealand’s Plant & Food Research Institute (formerly HortResearch) has maintained a breeding program over the last two decades and plans to release several cultivars in the near future. A multinational effort formed in 2012, IFORED, has begun to plant pre-commercial orchards of three red-fleshed cultivars for market evaluation. Recently, a grower-led breeding group, Midwest Apple Improvement Association (MAIA), initiated a breeding/selection effort. A significant hurdle for red-flesh culinary variety development is that, along with anthocyanins, red-fleshed varieties tend to accumulate other flavonoids in the fruit flesh, and these compounds contribute a bitter taste to the fruit. Thus, there is a trade-off between color and palatability, such that the most highly pigmented fruit are the least suitable for culinary use. Accordingly, cultivars now in development for culinary use have only moderate levels of anthocyanins in the flesh.

Rediscovery and evaluation of red-juiced cultivars for Great Lakes production

Although cultivars and breeding selections with very high levels of anthocyanins in the flesh wouldn’t be acceptable for culinary use, they would have immense potential value as a source of anthocyanins. An important feature of red-fleshed apples is that the anthocyanins are soluble, such that under typical pressing conditions, the juice color ranges from pink to dark red. In 2007, a group of MSU researchers including ourselves, Drs. Muralee Nair and Randy Beaudry, began to discuss the potential for red juice and extractable anthocyanins as novel products for Great Lakes apple growers. Our initial analysis of juice from ‘Niedwetskyana’ and two other cultivars was promising (Mulabagal et al. 2007). This juice contained up to > 1 mg anthocyanins/g of fresh weight. This concentration can exceed that of cherry or blueberry, two fruits considered to be very high in anthocyanins. We also determined that the juice was strongly active in standard biochemical assays designed to measure antioxidant potential (Mulabagal et al. 2007). In subsequent research, we found that this antioxidant capacity was at least three times, and up to five times, as high as that of typical apple juice. To emphasize our focus on juice and extractable anthocyanin, as opposed to culinary use, we refer to the cultivars we are studying as “red-juiced” rather than “red-fleshed”.

In 2010, we began evaluating red-juiced cultivars for potential production under Great Lakes environmental conditions. The first step was to identify known cultivars, and to catalog these in terms of desirable growth and production traits. In addition to the large USDA apple germplasm collection in Geneva, NY, we visited the Canadian germplasm collection in Harrow, Ontario, as well

as the Brogdale National Fruit Collection in the United Kingdom. In total, we examined nearly 3,000 distinct cultivars, and identified the red-juiced trait in more than 100 of these (van Nocker et al. 2012). We carried out visual evaluation of these cultivars, as well as examined historical records, where available, describing disease and production traits. These traits included resistance to fire blight, apple scab, powdery mildew, and cedar apple rust, as well as tree vigor, yield, and, where records were available, fruit characteristics.

Based on this data, we selected a subset of cultivars that were apparently disease-resistant, had potential to produce fruit with good color and juice qualities, and that might perform well under Great Lakes conditions. Representatives of these cultivars were observed in the field over one growing season, and 10 cultivars were selected for further study (Table 1). Scionwood was obtained and grafted to dwarfing rootstocks, and trees were planted in a high-density system (Slender spindle, 3' plant spacing, 10' row spacing; 1452 trees/acre). Our implementation of a high-density system was in recognition of the fact that, with future production, fruit for non-culinary purposes is likely to be harvested mechanically. The planting was established in Clarksville, Michigan, a location that represents the general climatic conditions of the Great Lakes region.

Once in full production, the cultivars were evaluated over a three-year period (Table 1). None of the ten cultivars showed symptoms of fire blight, cedar apple rust, or powdery mildew, even though these pathogens were clearly present in nearby plantings. All cultivars except 'Otterson' showed symptoms of apple scab. The most affected cultivar was 'Cowichan', which was completely defoliated by the first frost date in each year. 'Otterson' stood out as showing the most vigorous growth, attaining full size one year in advance of other cultivars. The highest yielding cultivars were 'Cranberry', 'Irene', and 'Otterson', which all produced > 20 tons per acre over the three-year period. Conversely, the very small fruited 'Prairie Fire' and 'Red Silver' yielded < 2 tons per acre. Extractable juice content ranged up to > 0.9 ml/g ('Cranberry'), which was similar to the reference cultivars 'Honeycrisp' and 'McIntosh', down to less than 0.5 ml/g ('Red Silver'). We also measured total phenolics content. Phenolics contribute to antioxidant activity, and impart a bitter taste to juice. Phenolics content for all cultivars was at least ten-fold greater than that found for the reference cultivars, and varied from a low of 46 mg/ml ('Otterson') to up to 92 mg/ml ('Selkirk'). The cultivars showed remarkably similar antioxidant potentials, which were ~ 2–3-fold greater than that of the references. Anthocyanin content varied by over ten-fold, with 'Cowichan' the

Table 1. Growth and juice characteristics of selected red-juiced cultivars. Designated representatives of each cultivar (n=20) at the Clarksville, MI trial site were observed over a three-year period. Values given for fruit are based on the mean and standard deviation from three biological replicates, each comprising >10 fruits. Disease (apple scab) ratings were based on a three-point scale, with (+++) indicating absence of visible disease, and (+) indicating obvious disease. Vigor was estimated subjectively based on a four-point scale, with (+++++) points assigned to the most vigorous (Otterson). Yield was estimated based on crop in the final two years. nd = no data taken.

Cultivar	Disease resistance	Vigor	Estimated yield (tons/acre)	Fruit diameter (cm) and mass (g)	Extractable juice content (ml/g)	Total phenolics	Antioxidant capacity	Extractable anthocyanin content (mg/ml)	Titrateable acidity (g/L)	Extractable juice/acre	Extractable anthocyanins/acre (kg)
Cowichan	+	+++	12.5±0.8	3.2±0.30 17.1±2.3	0.76	65-73	0.13	0.1	0.095	6,840 l 1,805 gal	0.68
Cranberry	++	++	20.8±1.9	4.2±0.30 51.0±9.0	0.92	83-87	0.14	0.63	0.112	13,778 l 3,635 gal	8.68
Henrietta Crosby	++	++	5.5±0.42	2.8±0.27 10.8±1.1	0.88	56	0.14	0.22	0.278	3,485 l 920 gal	0.77
Irene	+++	+++	24.2±2.8	4.3±0.37 35.6±4.3	0.88	66-70	0.13	0.18	0.197	15,333 l 4,045 gal	2.76
Otterson	+++	+++++	21.0±4.3	7.1±0.55 158±12	0.84	46	0.13	0.64	0.092	12,701 l 3,351 gal	8.13
Prairie Fire	++	++	1.6±0.11	1.4±0.22 1.4±.22	0.61	57	0.14	0.55	0.373	703 l 185 gal	0.39
Red Silver	++	+++	1.1±0.17	1.7±0.29 2.3±0.17	0.45	64-77	0.14	0.73	0.19	356 l 94 gal	0.26
Selkirk	++	+++	5.0±0.53	3.0±0.35 12.1±3.2	0.78	86-92	0.13	0.18	0.205	2,808 l 741 gal	0.51
Sissipuk	+	++	1.8±0.09	3.7±0.50 23.4±4.1	0.76	76-79	0.13	0.57	0.205	985 l 260 gal	0.56
Timiskaming	+++	+++	5.8±0.4	5.7±0.76 88.9±10.4	0.88	70-74	0.14	1.29	0.32	3,675 970 gal	4.7
Honeycrisp (reference)	nd	nd	nd	nd	0.88	<5	<0.05	<0.01	0.075	nd	nd
McIntosh (reference)	nd	nd	nd	nd	0.91	<5	<0.05	<0.01	0.109	nd	nd

lowest and ‘Timiskaming’ the highest. All cultivars generally contained higher acid levels than the reference cultivars, with ‘Prairie Fire’ having five-fold higher acid levels than ‘Honeycrisp’. Given the goal of juice production, ‘Cranberry’, ‘Irene’, and ‘Otterson’ were far superior to other cultivars, producing at least 3,300 gal/acre. With the goal of extractable anthocyanins, ‘Cranberry’ and ‘Otterson’ were again top performers, with potential yields of >8 kg/acre.

Based on these evaluations, we selected ‘Cranberry’ and ‘Otterson’ for further propagation and planting (Figure 2). ‘Cranberry’ was developed by R. L. Wodarz of Wyndmere, North Dakota and was released in 1953 (Jefferson 1970). As mentioned above, this cultivar is moderately susceptible to scab, but relatively free of the other evaluated diseases (Table 1). It is quick to come into production, and produces large amounts of egg-shaped fruit. Its dark red juice exhibits intense fruit flavors, reminiscent of strawberry and/or raspberry, with mild astringency. ‘Otterson’ is of unknown heritage, but was entered into the National Apple Germplasm Repository in March of 1992. In our trials, this cultivar is completely free of disease, is very vigorous, and produces high yields of relatively large fruit. The fruit yields large quantities of deep red juice with a subtle flavor profile and significant astringency (Table 1 and Figure 2).

Trial production of hard ciders using red-juiced apples

We recently initiated experiments to evaluate the potential for using ‘Cranberry’ and ‘Otterson’ in the production of hard (alcoholic) cider. Each cultivar offers a unique flavor profile, while serving as a source of red color, phenolics, and acid. Fruit were blended into a mix of non-red-juiced culinary apples during pressing (blending juices is a common practice in cider production, because it can create a more consistent product). In 2015, a blend of ‘Cranberry’ to equal parts ‘Jonathan’, ‘McIntosh’, and ‘Red Delicious’ was pressed and fermented (Figure 2). The resulting cider was a dark pink in color immediately after fermentation but oxidized to a light red-orange color following a secondary bottle fermentation. In 2016, ‘Otterson’ was pressed with an equal volume of ‘Mutsu’, yielding a dark red juice. In addition, a second pressing consisted of ‘Red Delicious’, ‘Ida Red’, and ‘Mutsu’ pressed through ‘Otterson’ pomace. Both of the 2016 batches exhibited very little color change, even after a secondary bottle fermentation. All trial batches were submitted as entries into the Great Lakes International Cider and Perry Competition (Grand Rapids, MI). The ‘Cranberry’ blend was awarded a gold medal in 2015 and was considered for best in show within the non-commercial category. In 2016, the ‘Otterson’ x ‘Mutsu’ and ‘Otterson’ pomace ciders earned a bronze and silver medals, respectively. Based on these initial successes, the potential to use these two varieties in large-scale production is very high. Recently, we partnered with a commercial producer, Short’s Brewing Company (Bellaire, MI), who used ‘Otterson’ in the production of their “Flamingo Juice” cider brand (Starcut Ciders 2016). This cider has earned a respectable score of 3.8/5 in user reviews through the UnTapped application.

PureRed Apples: A breeding project for improved red-juiced cultivars

Although ‘Cranberry’ and ‘Otterson’ have many excellent production and juice qualities, and so far seem to be suitable for large-scale production in the Great Lakes region, these cultivars also have limitations. For example, ‘Cranberry’ fruit is relatively small, and trees are incompletely resistant to scab. ‘Otterson’, on the other hand, produces fruit with mediocre taste and relatively low

acid. In 2015, we initiated a small breeding project at MSU with the goal of developing improved, red-juiced cultivars for Great Lakes production. This project, which we call PureRed, focuses

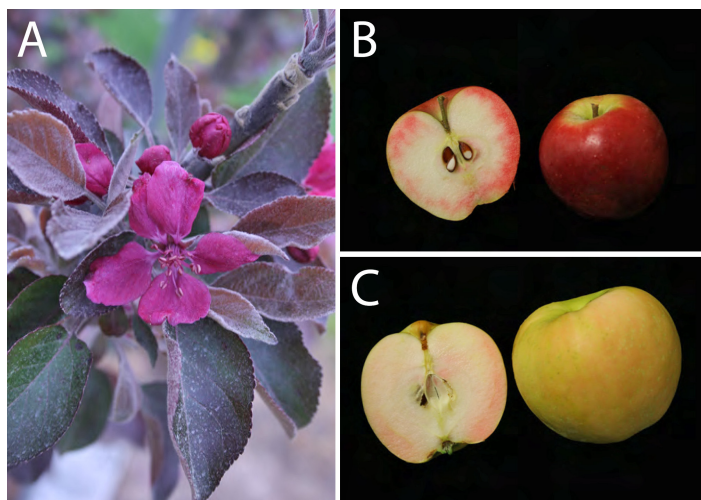


Figure 1. Representative red-fleshed cultivars. (A) ‘Niedwetskyana’ spring foliage and flower, showing purple coloration. (B) ‘Niedwetskyana’ fruit. Anthocyanin accumulation can be seen in the outer cortex. (C) ‘Pink Pearl’ fruit. Subtle coloring is seen in the outer cortex.

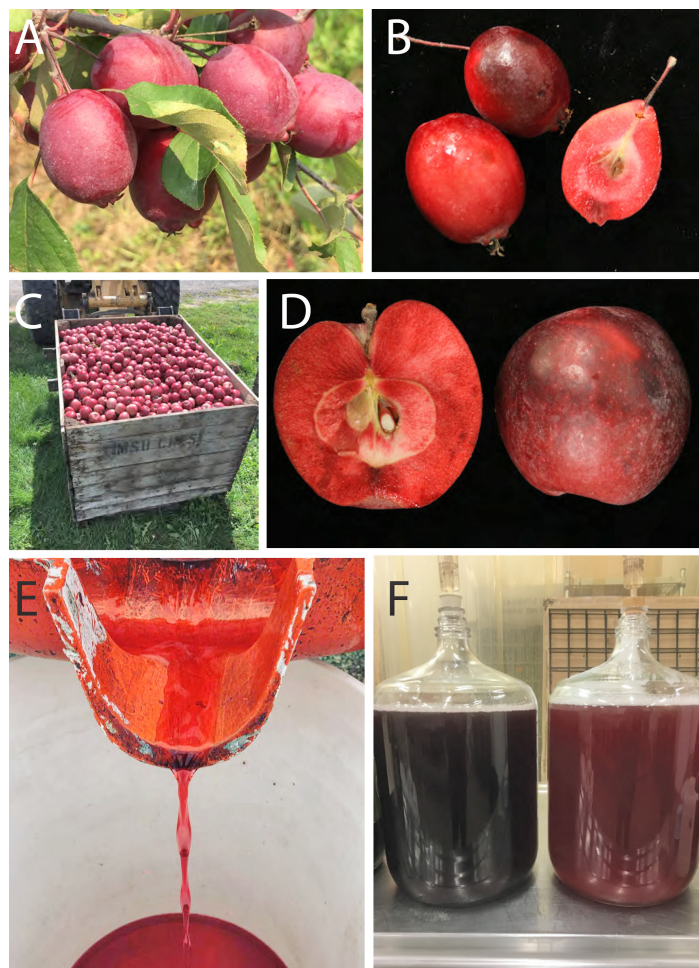


Figure 2. ‘Cranberry’ and ‘Otterson’. (A, B) ‘Cranberry’ fruit, at maturity. (C, D) ‘Otterson’ fruit, at maturity. (E) Juice from ‘Otterson’, blended with non-red juice at a 1:1 ratio. (F) Fermentation carboys illustrating juice color intensity; ‘Otterson’ x ‘Mutsu’ (left) and ‘Otterson’ pomace (right).

on further enhancing juice color and anthocyanin content, while also maintaining good trait qualities for vigor, production, disease resistance, and juice flavor, phenolics and acid content.

Enhancing anthocyanin content relies on our knowledge of the genetics of the red-fleshed trait, combined with a breeding technique called marker-assisted selection. Scientists at the University of Auckland and the Plant & Food Research Institute found that the red flesh trait in the cultivar 'Red Field' is due to increased activity of a specific gene, called *MYB10* (Espley et al. 2006). This gene acts as a master regulator of the anthocyanin biosynthetic pathway, and in typical apples is active only in the skin. In 'Red Field', the *MYB10* gene became active throughout the entire tree (Espley et al. 2006). Our previous work evaluating the range of red-fleshed cultivars found that the hyperactive allele of this gene was responsible for essentially all of the red-fleshed apple cultivars found in germplasm collections (van Nocker et al. 2012). We also found that this allele acts in a semi-dominant manner, such that two copies (homozygosity) are required for full effect. Finally, we found that, although this allele was necessary for the red-fleshed trait, at least one additional gene acts to enhance or repress its function (van Nocker et al. 2012). Creating an improved, "anthocyanin supercharged" cultivar is possible through managed crosses of cultivars containing the hyperactive *MYB10* allele, and selection of progeny plants that are both homozygous for the allele and that contain the genetic enhancer. Selection of progeny can be done quickly by directly analyzing DNA from the seedlings. Currently, we have selected and are propagating ~1,000 such progeny derived from intercrossing of 'Robert's Crab', 'Cranberry', 'Otterson', and five additional cultivars. The oldest progeny from these crosses will produce fruit suitable for evaluation in the coming season (2018). We hope that these new cultivars can be further evaluated and propagated through future partnerships with Great Lakes food and health-related interests.

Red-juiced apples as a potential new market for Great Lakes growers

The future of the Great Lakes apple industry may depend on the development of specialty crops of universal appeal that are optimized for our production region. There is tremendous opportunity to promote apple as a source for nutraceuticals (nutrition/pharmaceutical) and functional food. Nutraceuticals are defined as processed foods or food extracts that have a medicinal effect on human health. Functional foods are defined as normal components of the human diet that have health-beneficial effects. As the apple is already perceived among the public as the ultimate functional food, it has the highest potential for any fruit to be developed as a source of nutraceuticals. Anthocyanins and flavonoids in general have been well documented to benefit human health as antioxidants, a base of the multi-billion-dollar nutraceutical industry. Anthocyanins are available from other sources, such as purple cabbage and blueberry, but their extraction from apple will be facilitated by the current infrastructure devoted to apple juice processing.

Finally, as valuable as these applications may be, anthocyanins may have much greater potential value in the rapidly growing renewable energy industries. The chemical structure of anthocyanins allows for unique light energy absorption. For this reason,

these compounds are being evaluated for use in organic photovoltaics and to enhance light-harvesting properties of silicon-based photovoltaics (Amelia et al. 2015; Putri et al. 2015). Thus, we feel that there is tremendous potential for red-juiced cultivars in the coming decades.

Note: Scionwood for the cultivars discussed in this article can be obtained from the authors and from the USDA-ARS Plant Genetic Resources Unit, 630 West North St., Geneva, New York 14456-0462. USDA Germplasm accession numbers for 'Otterson' and 'Cranberry' are as follows: 'Cranberry' – PI589180; 'Otterson' – PI590178.

Acknowledgements

The research described in this article was supported by grants from the Michigan Apple Committee and Michigan Department of Agriculture and Rural Development.

References

- Amelia, D., Sawitri, D., Risanti, D. D. 2015. Co-sensitized natural dyes potentially used to enhance light harvesting capability. *Proc. Internat. Sem. Photonics Optics Applicat.* 9444.
- Espley, R. V., Hellens, R.P., Puterill, J., Kutty-Amma, S., Allan, A. C. 2006. Red colouration in apple fruit is due to the activity of a MYB transcription factor, MdMYB10. *Plant J.* 49: 414–427.
- Jefferson, R. M. 1970. History, Progeny, and Locations of Crabapples of Documented Authentic Origin. Washington, D.C., Agric. Res. Serv., U.S. Dept. Agric.
- Mulabagal, V., van Nocker, S., Dewitt, D., and Nair, M. 2007. Cultivars of apple fruits that are not marketed with potential for anthocyanin production. *J. Agric. Food Chem.* 55: 8165–8169.
- Putri, I. E., Sidik, M. L., Wahyuono, R. A., Sawitri, D., Risanti, D. D. 2015. Co-Sensitization Promoted Light Harvesting Capability of Dye-Sensitized Solar Cell (DSSC) Using Anthocyanin-Based Dye. *Adv. Mater. Res.* 1123: 325–328.
- Starcut Ciders. 2016. Flamingo Juice and Otterson Apples. Starcut Cider Blog, 19 Feb. 2016, www.starcutciders.com/tag/flamingo-juice/
- van Nocker, S., Berry, G., Najdowski, J., Michelutti, R., Luffman, M., Forsline, P., Smerirat, N., Beaudry, R., Nair, M., Ordidge, M. 2012. Genetic diversity of red-fleshed apples (*Malus*). *Euphytica* 185: 281–293.
- van Nocker, S., and Gardiner, S. E. 2014. (Review) Breeding better cultivars, faster: Applications of new technologies for the rapid deployment of superior horticultural tree crops. *Hortic. Res.* 1: 14022.

Steve van Nocker is a Professor of Horticulture at Michigan State University. His research focuses on the genetics of growth and development in horticultural crops, especially apple. **Christopher Gottschalk** is a PhD student in the MSU Department of Horticulture, and works on control of flowering in apple. He manages the Great Lakes Cider Apple Collection, which is supported by MSU and the Michigan State Horticultural Society. [Email: vannocke@msu.edu]

Evaluation of newer biologicals and the SAR-activator candidate Regalia in fire blight control applied by spraying or trunk injection

Srđan G. Ćimović and Christopher L. Meredith

Plant Pathology and Plant-Microbe Biology Section, Cornell University, New York State Agricultural Experiment Station, Highland and Geneva, NY

This research was partially supported by the New York Apple Research and Development Program

The 2016 fire blight epidemic caused severe losses in young apple orchards in northeastern and western New York (NY). Based on studies associating global warming

“Previous research on biologicals, plant-growth reducers, activators of Systemic Acquired Resistance (SAR), and copper, has shown medium to low efficacy under high disease pressure, and inconsistent results, depending on location-specific climate conditions and tree age. (This) led us to determine the efficacy of newer bio-control products and an SAR-activator candidate Regalia for blossom and shoot blight management.”

with changes in plant pest ranges and degree of infestations, we predict that years with very favorable weather for fire blight epidemics will become more frequent in cool climate regions of the US and the rest of the world (Pautasso et al. 2012; Bebber et al. 2013; Rosner

2015). Besides losses in yield, young trees, and costs of removal of dead trees and wood, plus orchard re-planting costs, some farms in NY applied several bactericide sprays long after the infections had become established on opened flowers at the end of bloom. Even though this practice can prevent further pathogen spread to new shoots, surface-sprayed bactericides are ineffective once the fire blight bacterium *Erwinia amylovora* enters the apple xylem or bark. In cases where, instead of copper, streptomycin was used after the infections became visible, repeated applications of this antibiotic might have increased the risk of streptomycin resistance acquisition in *E. amylovora* populations. Resistance to streptomycin can lead to blossom blight control failures due to loss of antibiotic efficacy. This would require use of a more expensive but very effective antibiotic such as kasugamycin, or less effective alternatives under high-disease pressure, such as biologicals, SAR compounds, and growth reducers such as prohexadione-calcium (Sundin 2014). Streptomycin efficacy should be preserved by applying it only when fire blight prediction models indicate that flower infections can occur (e.g., NEWA's EIP and Cougarblight, Maryblyt, RIMpro). After the bloom is over, streptomycin should be applied only following hail events when streptomycin is needed, to prevent severe trauma blight infections through hail injury wounds on trees.

Due to prevalent use of antibiotics in animal production and occurrence of antibiotic resistance in clinical pathogens in hospitals, antibiotics are not considered to be as acceptable for use in agriculture as they were in the past. Even though the mechanisms for transferring the resistance genes are distinct between human and plant pathogens (Sundin 2002), fear of potential transfer of antibiotic resistance from environmental bacteria to clinical pathogens promotes scrutinized use of antibiotics in all agriculture. As of 2014, use of antibiotics is prohibited in organic apple production. In addition, effective bactericides for plant protection are becoming very rare and difficult to get approved by EPA. Finally, due to toxic effects of metallic copper on soil fauna, per-acre yearly limits on spray-use of copper products are currently being reconsidered. However, the main benefit of copper as a bactericide is that low rates can be used to prevent spread of secondary shoot blight infections during the summer. In search of alternative plant protection materials for fire blight, previous research on biologicals, plant-growth reducers, activators of systemic acquired resistance (SAR), and copper, has shown medium to low efficacy under high disease pressure and inconsistent results, depending on location-specific climate conditions and tree age.

The complex status of products available to control fire blight led us to determine the efficacy of newer biological control products Prestop (*Gliocladium catenulatum* strain J1446, 10^8 CFU/g), MBI-110 AF5 (*Bacillus amyloliquefaciens* strain F727), and an SAR-activator candidate Regalia/MBI-10612 (5% and 12% extract of plant *Reynoutria sachalinensis*) for blossom and shoot blight management (Table 1). The fungus *G. catenulatum* is a known fungal antagonist that primarily inhabits soils. The strain J1446 of this fungus in Prestop was isolated from Finnish field soil and has been tested or shown some efficacy in foliar, flower/fruit, and root diseases on tomato, strawberry and raspberry (Karise et al. 2016). On apples, preliminary trials show that Prestop reduces incidence of core rot of apple caused by flower infections of *Fusarium avenaceum* and *Botrytis cinerea*. Primary modes of action of this biocontrol fungus consist of its strong ability to colonize roots, foliage, and flowers, and outcompete the plant pathogenic fungi. Some tests showed that *G. catenulatum* parasitizes certain plant pathogenic fungi, has antagonistic enzyme activity against fungi, and could trigger induction of plant resistance after root treatments.

Besides sprays, we also tested two formulations of Regalia applied via trunk-injection(s). Our previous research on mature

Table 1. Treatments with sprayed biologicals and SAR-activator candidate Regalia/MBI-10612, alone or in combination with copper, used for blossom and shoot blight control on ‘Honeycrisp’ apple trees. Treatments in bold were trunk-injected.

No.	Product	Active ingredient	Times applied and amount per acre	Metallic copper per amount of product	Metallic copper equivalent sprayed in lb/A
1	Prestop WG	<i>Glucadium catenulatum</i> Strain J1446	2X 35 oz / A	/	/
2	Prestop WG	<i>Glucadium catenulatum</i> Strain J1446	2X 70 oz / A	/	/
3	CS2005 + Regalia	19.8% copper sulfate pentahydrate + 5% extract of plant <i>R. sachalinensis</i>	2X 16 fl oz / A + 32 fl oz / A	0.418 lb/gal	2 x 0.052 lb/A
4	CS2005 + Regalia	19.8% copper sulfate pentahydrate + 5% extract of plant <i>R. sachalinensis</i>	1X 47.7 fl oz / A + 95.4 fl oz / A	0.418 lb/gal	1 x 0.160 lb/A
5	Regalia	5% extract of plant <i>R. sachalinensis</i>	2X 64 fl oz / A	/	/
6	Regalia	5% extract of plant <i>R. sachalinensis</i>	3X 64 fl oz / A	/	/
7	MBI-10612	12% extract of plant <i>R. sachalinensis</i>	2X 32 fl oz / A	/	/
8	MBI-110 AF5	<i>B. amyloliquefaciens</i> strain F727	2X 64 fl oz / A	/	/
9	MBI-10612 Trunk-injection	12% extract of plant <i>R. sachalinensis</i>	2X 32 fl oz / A	/	/
10	Regalia Trunk-injection	5% extract of plant <i>R. sachalinensis</i>	2X 76.8 fl oz / A	/	/
11	MBI-10612 Trunk-injection	12% extract of plant <i>R. sachalinensis</i>	4X 32 fl oz / A	/	/
12	Harbour + Regulaid	17% streptomycin + 90.6% 2-butoxyethan- ol, poloxalene, monopropylene glycol	2X 1.5 lb / A + 3 pts	/	/
13	Fireline 17 WP	17% oxytetracycline	2X 1 lb / A	/	/
14	Untreated Control	/	/	/	/

‘Gala’ apple trees demonstrated that trunk-injected phosphites (Phospho-Jet) and acibenzolar-S-methyl, (Actigard), a known SAR-activator, induce plant defense response in apple leaves (Aćimović et al. 2015). SAR is a broad-spectrum defensive resistance response towards plant pathogens that is induced in plants by a localized exposure to a pathogen or after spraying with a synthetic or natural compound, known as an SAR inducer or activator (Hammerschmidt 2007). SAR induction results in a myriad of synthesized and accumulated defensive compounds, including antimicrobial proteins, that help the plant to suppress the disease. In our trial, Regalia was also evaluated mixed with a copper product CS2005, in the hope that this combination would provide better efficacy (Table 1). Besides efficacy, we also evaluated the potential of these eco-friendly and/or organically acceptable products to cause fruit russet. In this paper, we present this data along with the fruit russet data for low-rate copper treatments applied at bloom and published in a previous Fruit Quarterly article (Aćimović and Meredith 2017).

Can Preventive Applications of Prestop, MBI-110 AF5, and Regalia/MBI-10612 Suppress Blossom and Shoot Blight Under High Disease Pressure?

On 26 Apr 2017, ‘Honeycrisp’ trees were at pink growth stage. On 27 Apr, bloom reached 63% due to extremely warm weather. On 29 Apr, when Honeycrisp trees were at 65–70% king bloom opened, treatments in Table 1 and Figure 1 were applied using a gas-powered backpack airblast sprayer delivering 50 gal/A (Solo 451 Mist Blower, 3 gal). This volume was used and the treatments were timed to avoid slow-drying conditions that could promote

fruit russetting. Fireline was delivered in 100 gal/A and 1X CS2005 + Regalia in 150 gal/A. To apply the same amount of each tested product as one apple tree would receive from a tractor airblast sprayer in a high-density apple orchard, we divided the treatment rates per acre by 940 trees/A, which is the lower limit for the number of planted trees in a high-density orchard. We used timed applications with the backpack sprayer to apply the appropriate amounts of product per tree (Table 1). In the treatments with two sprays (Table 1), applications on 29 Apr were ~15 min apart because the flower opening was so rapid that sprays could not be applied as planned at 20 and 50% king bloom for all the treatments, except at 50, 80, 100% king bloom for the 2X CS2005 at 16 fl oz + Regalia 32 fl oz treatment and for the 2X Regalia 64 fl oz treatment, and at 50, 80% king bloom, petal fall, first cover for the 2X MBI-110 AF5 at 64 fl oz treatment and the 2X MBI-10612 at 32 fl oz treatment (Table 1). The 3X Regalia 64 fl oz treatment was sprayed the first time on 28 Apr, and the second and third time both on 29 Apr, ~15 min apart, instead of the planned three sprays at pink, 20%, and 50% king bloom (Table 1). Applications for the trunk injection treatments in Table 1 were made at half-inch green (16 Apr) and at pink (24 Apr) for 2X MBI-10612 at 32 fl oz and for 2X Regalia at 76.8 fl oz, while for 4X MBI-10612 at 32 fl oz applications were made at half-inch green (16 Apr), pink (24 Apr), petal fall (7 May), and at first cover (17 May).

We inoculated flowers on 30 Apr by misting entire ‘Honeycrisp’ trees with a water suspension of 3×10^6 CFU/ml of *E. amylovora*, at 80% king bloom (GroundWork® rolling cart sprayer, 30 PSI, 3 gal). We used a slightly higher amount of inoculum than the usual 1×10^6 CFU/ml due to the low average daily temperature

of 52.7°F. First fire blight symptoms developed on 17 May. RIMpro fire blight forecast model connected to the on-site NEWA weather station in Highland, NY, where the experiment was conducted, issued a prediction on 29 Apr at 7:30 pm that natural fire blight infections were possible on 30 Apr and 2 May, based on the weather forecast.

We rated blossom and shoot blight incidence on 27 May and 3 Jun, respectively (Figure 1A & B). Going around the crown, we randomly chose 100 flower clusters per tree and counted the number of diseased and healthy clusters in that sample. Flower infections migrated into the shoots. We randomly chose 100 shoots per tree and counted the number of infected and healthy shoots in that sample. Blossom and shoot blight were calculated as blossom and shoot blight percent on a per-tree basis. Mean percent of blossom and shoot blight incidences were calculated for each treatment from 4 single-tree replicates.

Overall, under high disease pressure, Prestop sprays during rapid bloom provided poor but statistically significant blossom blight reduction of 15.5%, while the higher rate provided 8.6% reduction, which was not different from the untreated control. This could be explained by the fact that in some species of biocontrol fungi, like *G. catenulatum* strain J1446, inhibition of their mycelial growth can occur if there are too many spores germinating at the same time. It therefore seems that there could be a trend in some biocontrol materials that “less is often more” in terms of the effectiveness. MBI-110 AF5 provided no blossom blight control. This indicates that more preventive sprays applied farther apart are probably needed during bloom to allow better growth and establishment of *B. amylovora* populations on the flower stigma and thus reduce fire blight infection.

A similar trend in poor control was visible for shoot blight incidence (Figure 1B). However, exceptions were 20% shoot blight control with 2X CS2005 + Regalia, 19% shoot blight control with sprayed 2X MBI-10612, and 35.7% shoot blight control with the highest rate of trunk-injected 2X Regalia treatment (Figure 1B). The fact that the highest rate of trunk-injected Regalia reduced shoot blight incidence by 36% implies that this plant extract product probably activates SAR defense response in apple trees, which leads to disease reduction. However, until the pathogenesis-related (PR) gene expression assays that prove the SAR response are conducted, the true mode of action, i.e., mechanism of Regalia activity, remains unconfirmed (Aćimović et al. 2015). In conjunction with the high rate, delivery of this extract into the plant by trunk injection seems to increase the efficacy of Regalia in shoot blight control in comparison to spraying. However, to prove this, the same rate should be applied by spraying and trunk injection. MBI-10612 or Regalia alone, or mixed with CS2005, did not control blossom blight. This indicates that the copper rates were probably too low to kill *E. amylovora* and that Regalia, an SAR-activator candidate, is probably not activating SAR in the green flower parts. When we tested the SAR

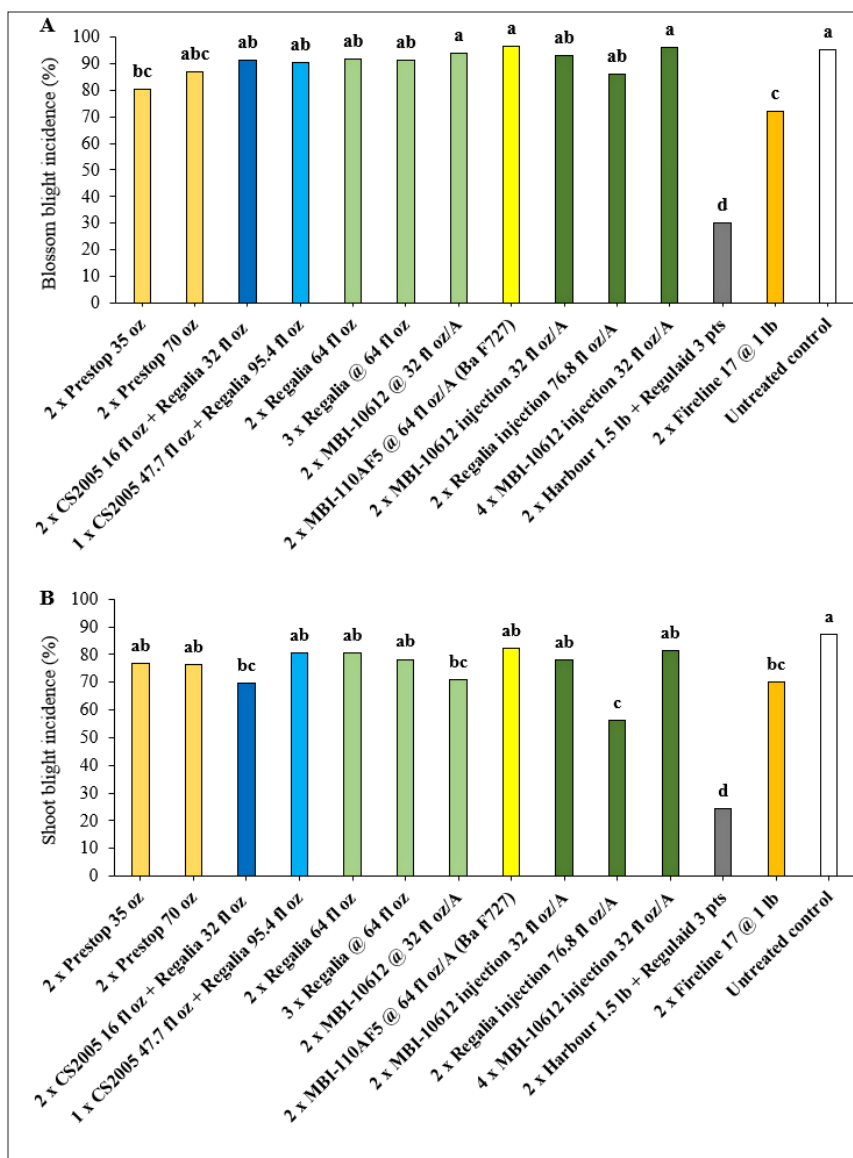


Figure 1. (A) Blossom blight and (B) shoot blight incidence on ‘Honeycrisp’ after preventive sprays of biologicals and sprays or trunk injections of SAR-activator candidate Regalia/MBI-10612. Trees were inoculated with fire blight bacterium *E. amylovora* at 80% king bloom opened (3×10^6 CFU/ml). Different letters above bars, within each graph, indicate significant differences between treatments ($P < 0.05$).

activator Actigard we did not detect the PR gene expression in green flower parts (Aćimović et al. 2015). Finally, it seems that there are no synergistic efficacy interactions between CS2005 and Regalia. Harbour provided blossom and shoot blight control of 68.5% and 72%, respectively.

What is the Potential of Prestop, MBI-110 AF5, and Regalia/MBI-10612 to Cause Fruit Russet?

In addition to fire blight control, we rated the fruit russet incidence for the treatments in Table 1 and for the copper spray treatments reported previously (Aćimović and Meredith 2017). Fruit russet forms if epidermal cells are damaged, sometimes during the first 30–40 days after petal fall. When fruit epidermis is damaged, a brown layer of cork cells forms in the lower epidermis and pushes outward, becoming visible on fruit surface as it matures (Pscheidt 2015). Cool weather in conjunction with a wet fruit surface, especially from pink growth stage until 3 weeks after petal fall, is conducive for russetting.

The 2017 weather conditions at the experiment location in Highland, NY, during the treatments and just after the applications, did not promote slow-drying of spray deposits that would allow fruit russet development. However, frequent rains in 2017 with cooler weather and high relative humidity, which lasted from 30 Apr to 15 May, and then from 19 May to 7 Jun, could have promoted russet formation in conjunction with the dried spray deposits (Figure 2). The percent incidence of fruit russet was calculated from the number of fruit with russet symptoms versus the russet-free fruit on 25 randomly selected fruit clusters per tree, summing up to 50 fruits per replicate. Mean percent of fruit russet incidences were calculated for each treatment from 4-single tree replicates.

Prestop and Harbour treatments showed the least fruit russet and did not differ from the untreated control (Figure 3A). 2X MBI-110 AF5 showed significantly higher russet compared with these treatments. Surprisingly, the high rate 2X Regalia trunk injection showed the next highest fruit russet incidence, followed by the 2X CS2005 + Regalia. This is unexpected, since 2 x Regalia in this treatment was not deposited on the surface of the flowers or fruit, but delivered through the apple xylem. If this plant extract is highly soluble in water, it is possible that it accumulated in immature fruit during development and size enlargement. However, since the incidence was not statistically different from the untreated control, it is difficult to speculate whether and how the trunk-injected Regalia reached and affected the fruit epidermis cells to cause russet.

Unexpectedly, there was no difference in russet incidence among the low-rate copper treatments, antibiotics, and the untreated control (Aćimović and Meredith 2017), leading us to believe that cool and rainy weather conditions during fruit growth

contributed to russet development across all treatments (Figure 3B). Nevertheless, many copper treatments resulted in numerically more russet in comparison to the untreated control.

Conclusion

Our evaluations of the newer biologicals Prestop, MBI-110 AF5, and an SAR-activator candidate Regalia/MBI-10612 showed overall poor control of blossom and shoot blight under the high disease pressure that evolved in our trial and under the rapid bloom scenario in 2017. Part of the reason for such results could be that, with the abrupt applications governed by the rapid flower opening, too short a time was available for these materials to trigger their respective modes of action, such as establishing larger populations for biocontrol of *E. amylovora* or inducing an SAR defense response, if that is Regalia's mode of action. Efficacy of the same treatments might be better in years with conditions less conducive to fire blight establishment and/or with flowers exposed to lower levels of inoculum. Results on fruit russet incidence indicate that even on 'Honeycrisp', this disorder can occur when weather conditions are favorable and/or spray product formulations contain damaging active ingredients or adjuvants.

Even though eco-friendly and/or organically acceptable options for management of fire blight are much more available today than before, their efficacy is still not as reliable as the efficacy of streptomycin and kasugamycin (Sundin 2014). This is especially true in years with high disease pressure due to very favorable conditions for fire blight development. In these situations, when infections can be predicted by disease prediction models, fire blight can become very destructive, leading to yield reduction and tree

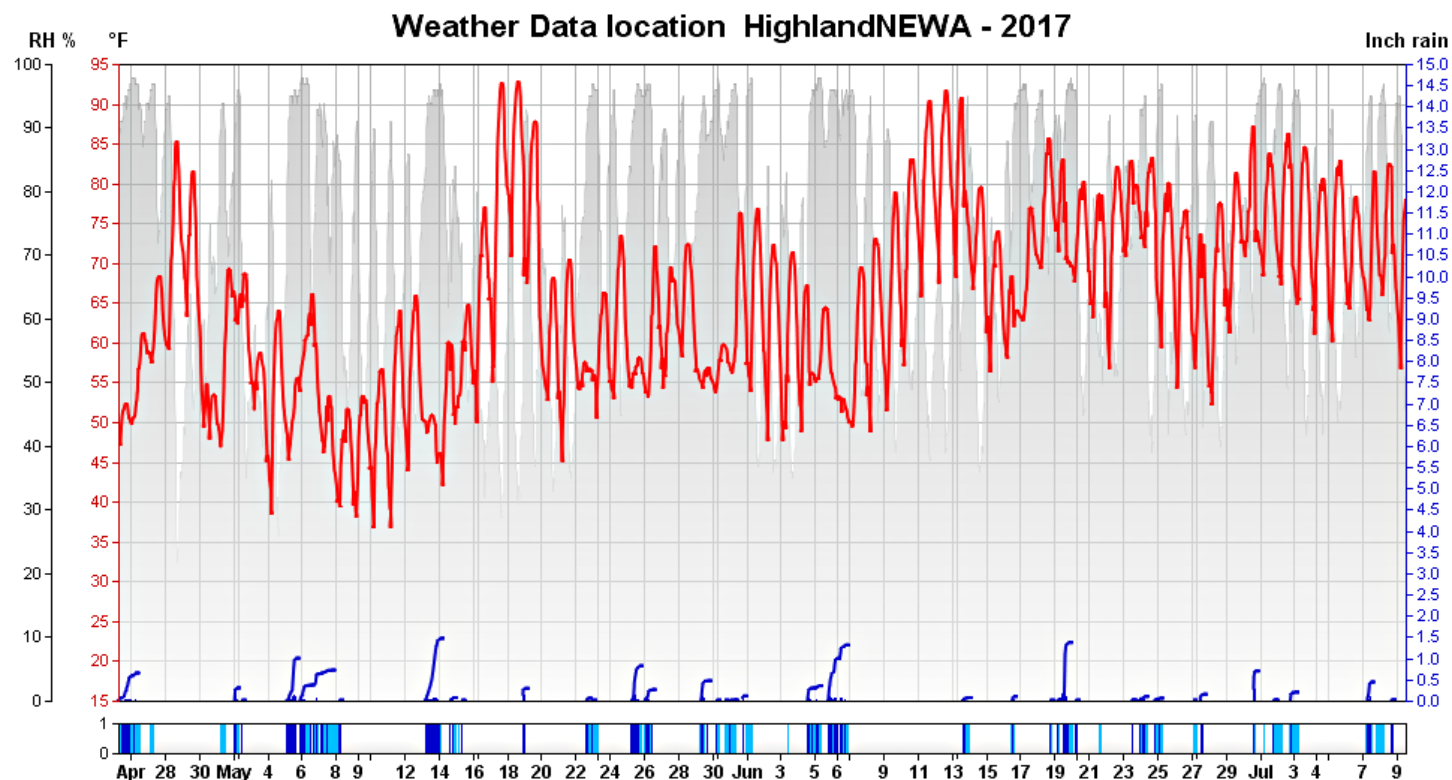


Figure 2. Summary of weather conditions from 27 Apr to 9 Jul 2017 from an on-site NEWA weather station in Highland, NY, during the fire blight efficacy trial on 'Honeycrisp'. Data are obtained from RIMpro Cloud Service, an interactive Decision Support System for pest and disease prediction and management in fruit and grape production. The upper main graph: red line represents temperatures (left y-axis in red), blue line/s are rain events indicating amount in inches (right y-axis in blue), gray background peaks show relative air humidity (RH) in % (far left y-axis in black). The bottom small graph with dates indicates the length of periods of rain (dark blue bars) and of wetting afterwards (light blue bars).

death if highly effective control materials are not applied. With the current technology used in apple production, including fire blight-susceptible varieties and rootstocks, spindle training systems with young fruiting limbs, high-density plantings, and the warming climate, it will be increasingly difficult to control fire blight. Until safe (i.e. non-russetting) and effective replacements for plant protection antibiotics are developed and registered, fire blight management will continue to be a challenge.

Acknowledgements

I thank the New York Apple Research and Development Program, Marrone Bio Innovations, BioForest Technologies Inc, Albaugh LLC, Brandt Professional Agriculture, and the Jentsch Lab at Cornell University's HVRL for financial, spray material sample, and equipment support in this research. I thank Dr. David Rosenberger for reviewing this manuscript and the faculty and staff of the Hudson Valley Research Laboratory for providing the research plot for this experiment and contribution in its maintenance.

References

- Ćimović, S. G., and Meredith, C. L. 2017. Evaluation of dormant copper sprays with bark penetrating surfactants in reduction of *Erwinia amylovora* in cankers and of low-rate copper sprays in blossom blight control. *Fruit Q.* 25(3): 15–20.
- Ćimović, S. G., Zeng, Q., Mcghee, G. C., Sundin, G. W., Wise, J. C. 2015. Control of fire blight (*Erwinia amylovora*) on apple trees with trunk-injected plant resistance inducers and antibiotics and assessment of induction of pathogenesis-related protein genes. *Front. Plant Sci.* 6: 16.
- Bebber, D. P., Ramotowski, M. A. T., Gurr, S. J. 2013. Crop pests and pathogens move polewards in a warming world. *Nat. Clim. Change* 3: 985–988.
- Hammerschmidt, R. 2007. Introduction: Definitions and Some History, in: Walters, D., Newton, A., Lyon, G. (Eds.), *Induced Resistance for Plant Defence*. Blackwell Publishing, pp. 1–8.
- Karise, R., Dreyersdorff, G., Jahani, M., Veromann, E., Runno-Paurson, E., Kaart, T., Smagghe, G., Mänd, M. 2016. Reliability of the entomovector technology using Prestop-Mix and *Bombus terrestris* L. as a fungal disease biocontrol method in open field. *Sci. Rep.* 6: 31650.
- Pautasso, M., Döring, T. F., Garbelotto, M., Pellis, L., Jeger, M. J. 2012. Impacts of climate change on plant diseases - opinions and trends. *Eur. J. Plant Pathol.* 133: 295–313.
- Pscheidt, J. 2015. Apple (*Malus* spp.)-Fruit Russetting [WWW Document]. *Pac. Northwest Pest Manag. Handb.* URL <https://pnwhandbooks.org/plantdisease/host-disease/apple-malus-spp-fruit-russetting> (accessed 10.19.17).
- Rosner, H. 2015. Pine Beetle Epidemic - The Bug That's Eating the Woods [WWW Document]. *Natl. Geogr.* URL <http://ngm.nationalgeographic.com/2015/04/pine-beetles/rosner-text> (accessed 10.17.17).

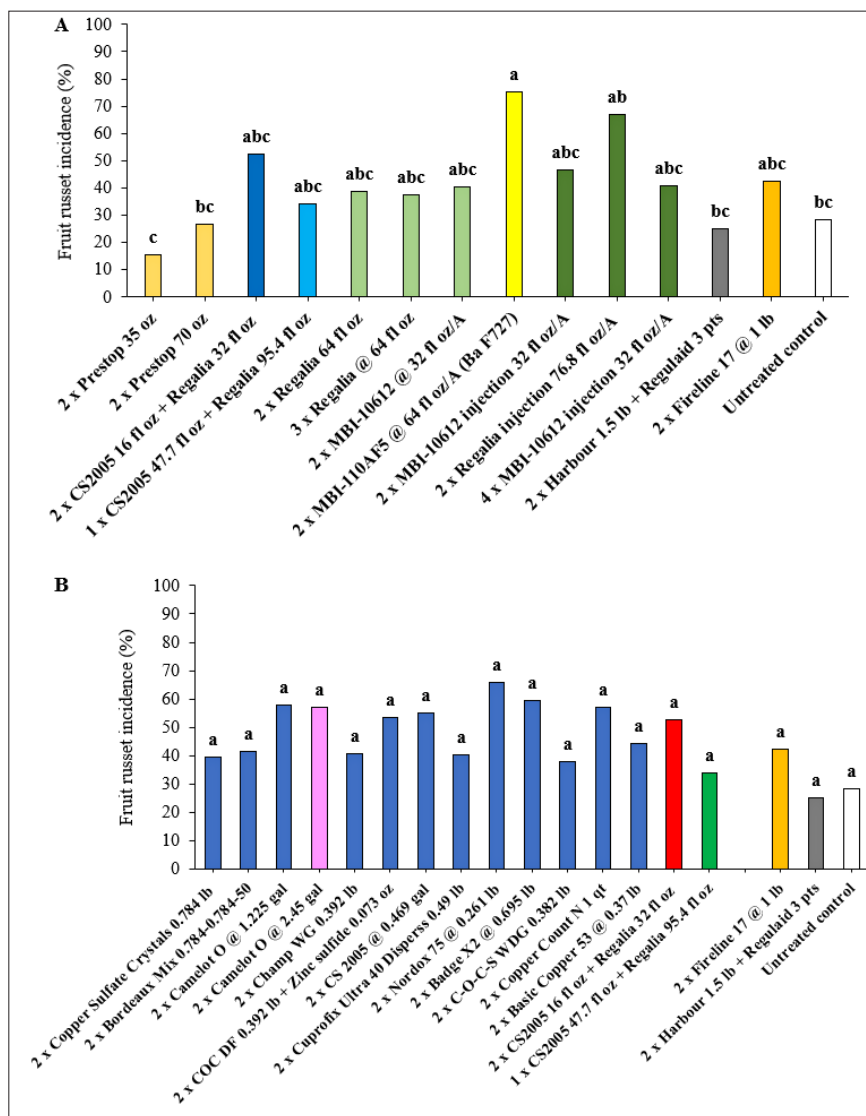


Figure 3. Fruit russet incidence on 'Honeycrisp' apple trees after (A) preventive sprays of biologicals and sprays or trunk injections of SAR-activator candidate Regalia/MBI-10612, and (B) after preventive sprays of copper products during bloom. Russet data in graph (B) is related to the copper sprays presented in Ćimović and Meredith (2017). Different letters above bars, within each graph, indicate significant differences between treatments ($P < 0.05$).

- Sundin, G. W. 2014. Managing fire blight: new lessons learned from the use of kasumin for blossom blight and apogee for shoot blight control. *NY Fruit Q.* 22(2): 9–13.
- Sundin, G. W. 2002. Distinct recent lineages of the *streptomycin*-resistance genes in clinical and environmental bacteria. *Curr. Microbiol.* 45: 63–69.

Srdan G. Ćimović is an Extension Associate in plant pathology leading an applied and basic research program aimed at improving disease control options for tree fruits at Cornell University's Hudson Valley Research Laboratory in Highland, NY. **Christopher Meredith** is a laboratory and field technician in the Ćimović lab helping in applied and basic plant pathology research aiming to improve disease control options for tree fruits at Cornell University's Hudson Valley Research Laboratory in Highland, NY.



Better Buildings Mean More Profit.

- Retail Sales
- Bin Storage Buildings
- NRCS Compliant Spray Buildings

Call Bill Murray and request a copy of the
Top 10 Questions to Consider Before Building!

FLC
FINGERLAKES CONSTRUCTION
fingerlakesconstruction.com

315-923-7777

P.O. Box 184
North Lakewood
WA 98259

360.652.4200
appletreeholder.com

UNIVERSAL
TREE GUIDE

PATENT PENDING

UNIVERSAL
TRELLIS CLIP

PATENTED IN USA & CANADA

frontdesk@evansmfgco.com

Fourth Generation Family Owned and Operated
Eastern Apple Supplier

EST. 1963

HUDSON RIVER FRUIT

DISTRIBUTORS

Grower | Packer | Shipper

1.800.640.2774
65 Old Indian Rd. | PO Box 246 | Milton, NY 12547
Info@HudsonRiverFruit.com | www.HudsonRiverFruit.com



**Crop
Production
Services**



Serving the Agricultural Industry in your area with professionals
who have the expertise and exclusive line of products you need
to succeed in today's competitive market.

As we welcome the
arrival of 2018,
Crop Production Services
would like to thank you
for your patronage.
May 2018 be safe
and prosperous.

Crop
Production
Services



Distributor for:

Adjuvants | Chemicals | Nutritional
Seed | Seed Treatments

**140 Office Parkway
Pittsford, NY 14534
(585) 586-1330 • www.cpsagu.com**

Expanding the Range of the Samurai Wasp, *Trissolcus japonicus*, in New York Orchards

Peter Jentsch

Department of Entomology, Hudson Valley Research Laboratory, Cornell University, Highland, NY

The stink bug complex is a robust and diverse group of insects found throughout the continental US. Although half an inch in length, some species can be elusive, and

“With the invasive complex of pests on the rise, significant losses in production and increased risk from elevated use of pest control measures are also present. The recent emergence of the Samurai Wasp, a viable biological control for the invasive brown marmorated stink bug, may prove to be a very welcome Asian warrior, now present in New York State.”

not easily seen in the wild or while scouting in agricultural commodities. We know them to be both predatory and beneficial in the agricultural system, as well as pests in our gardens and commercial crops. Stink bugs are in the order Hemip-

tera, or “True Bugs”, in the family Pentatomidae, which contains hundreds of distinct species, many of which are agriculturally important pest insects.

When these insects become disturbed, some species emit secretions of aldehydes produced from glands and released from pores in the thorax to create a vile odor, perceived as rancid almond to some, or with the fragrance of cilantro to others. These secretions are used for protection from predation. Some species utilize aldehydes in the late summer and fall to locate overwintering sites, where the insects aggregate and reside. These compounds, termed aggregation pheromones, have been synthesized and employed as monitoring tools for use in agricultural crop pest management.

Like all true bugs, adult stink bugs feed using mouthparts that form a rostrum: a very thin, hollow tube with a sharp tip, which is used to pierce plant tissue and remove liquids. As they feed, they inject saliva and enzymes to dissolve tissue prior to removing the liquid slurry. Damage to the plant during feeding and cell liquefaction first appears as darkening spots, with the development of further dimpling and callus flesh beneath the skin after 5–14 days. Discerning the difference between stink bug injury, bitter pit, and hail, can be a challenge. Yet, all stink bug feeding sites on the surface of the fruit have a minute puncture in the center, which, when undisturbed, may contain a feeding tube, a small sheath formed by salivary secretions (Figure 1).

The invasive Asian brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål) has been present in the northeast since 1996 (Hoebeke and Carter 2003). First confirmed on Adams Island in Allentown, Pennsylvania, the insect has so far been detected in 44 states and 4 Canadian provinces (Northeast IPM Center; Figures. 2, 3). The BMSB is extremely polyphagous, feeding on over 200 host plants including ornamental plants, small



Figure 1. Typical stink bug feeding site on apple. [Photo: HVRL, Highland, NY]



Figure 2. Two views of the brown marmorated stink bug. [Photo: D. Shetlar, Ohio State University Extension Entomology]

fruits, grapes, tree fruits and vegetable crops. Economic losses in the mid-Atlantic US and New York were widely documented in 2011–12. The pest has one to two generations per year in the mid-Atlantic and northeast, depending on seasonal temperatures. The insect requires 13.5 hours of day length as the initial biofix for emergence from overwintering sites, calculating 135 degree days (DD) (base 57.2°F) until first eggs are deposited onto foliage, and an additional 964 DD for BMSB eggs to develop through five instars to the adult (Wilson et al. 2016)

Biological Control of Brown Marmorated Stink Bug

A welcome warrior from Asia has recently appeared in the US to help in the fight to reduce the populations of invasive BMSB in our crops and homes. The Samurai Wasp, *Trissolcus japonicus* (Ashmead), is an egg parasitoid of stink bugs, utilizing BMSB

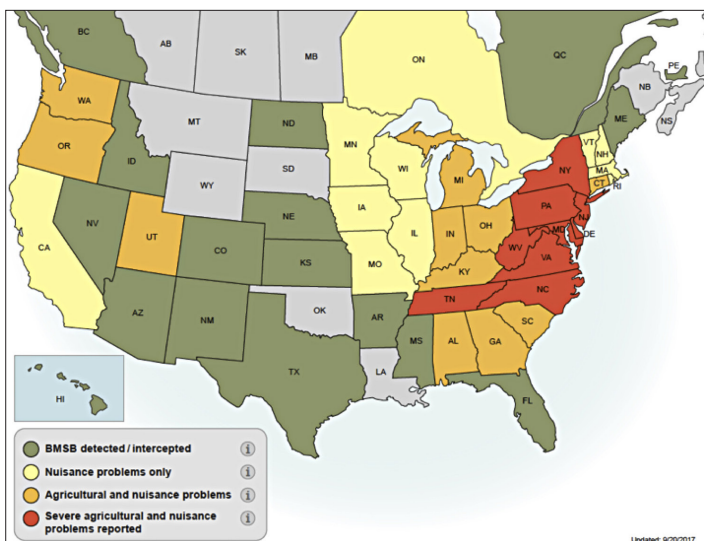


Figure 3. Distribution of the brown marmorated stink bug in 44 states and 4 Canadian provinces, 2017.

eggs for its own development and reproduction. It is capable of laying its own egg within each of a majority of the approximately 28 eggs found in a typical BMSB egg cluster. The wasp larva develops within the egg, feeding on the developing stink bug nymph, and destroying it within a few weeks, depending on temperature. A single adult Samurai Wasp then emerges from each stink bug egg, to repeat the cycle of parasitizing BMSB eggs over the course of the season.

In eastern Asia (China, Japan, and South Korea), the origin of the BMSB and Samurai Wasp, the wasp is credited for maintaining low levels of brown marmorated stink bug. The Samurai Wasp is considered the principal biological control agent of BMSB in Asia, with parasitism rates of up to 70%, and an average annual rate of 50% reduction of the population observed in the field (Yang et al. 2009). Because of its high parasitism rates and biological adaptations, the Samurai Wasp has the potential to be a strong biological control candidate of BMSB in the US.

An important aspect of the biology of the brown marmorated stink bug and Samurai Wasp is their host ecology. BMSB is an arboreal insect, overwintering, feeding, reproducing, developing and residing primarily in deciduous forest trees. It will often stay in tree host plants until populations overwhelm the system by reducing food resources, or until the host declines due to drought, or if the insect's requirements for resources increases. It will then move to crops containing needed food resources, including fats, carbohydrates and ample moisture, which is needed to initiate flight to sites where it will diapause throughout a 3- to 6-month overwintering phase.

Meanwhile, the Samurai Wasp is cold-hardy in regions where BMSB also survives the winter. The wasp, roughly 2 mm in length, is barely visible in the field, residing far enough

away from agricultural systems so as not to be heavily impacted by farm pest management activities. Its presence in the forest and orchard edges likely increases its success in the agricultural/forest landscape, where BMSB lay their eggs.

We know little about the feeding habits of *T. japonicus* in the northeast. The adult wasp does not feed on its host; yet, other scelionids, similar in habit to *T. japonicus*, feed on insect honeydew and the nectar of flowers (Safavi 1968; Orr 1988). Laboratory rearing of the Samurai Wasp depends on the provision of microliter droplets of dilute honey in petri dishes, on which they can survive very well.

Parasitoid Surveys

The adult Samurai Wasp was recently discovered as a non-native or adventive insect species, emerging from sentinel BMSB eggs in surveys for native parasitoid populations. The first find of the wasp by Don Weber (USDA) was from eggs of wild BMSB populations in Beltsville, Maryland in 2014 (Talamas et al. 2015), with several additional site survey findings in Maryland, Washington DC, and Winchester, Virginia during 2015, and in New York, Vancouver, Washington and Oregon in August 2016 (Milnes et al. 2016; Jentsch 2017). It is speculated that these wild populations of *Trissolcus japonicus* may have arrived within stink bug egg masses on plant cargo shipped from Asia.

NY Sentinel Egg Studies

Hudson Valley Research Laboratory colonies of brown marmorated stink bug were provided jalapeño pepper plants or field-collected leaves of Tree of Heaven, *Ailanthus altissima*, for both feeding and oviposition. BMSB eggs were flash frozen to -80° C for 4 minutes to kill developing stink bug nymphs and reduce the eggs' natural defense mechanism against successful native and invasive parasitoid development when parasitized after placement in the field.

Our initial sentinel survey conducted in the Hudson Valley in 2016 employed individual leaves containing frozen eggs. We fixed the eggs onto known host plants of black walnut (*Juglans nigra*) and Tree of Heaven in two sites at Hepworth Farms in Milton, NY. We began on 1 June, placing and collecting the

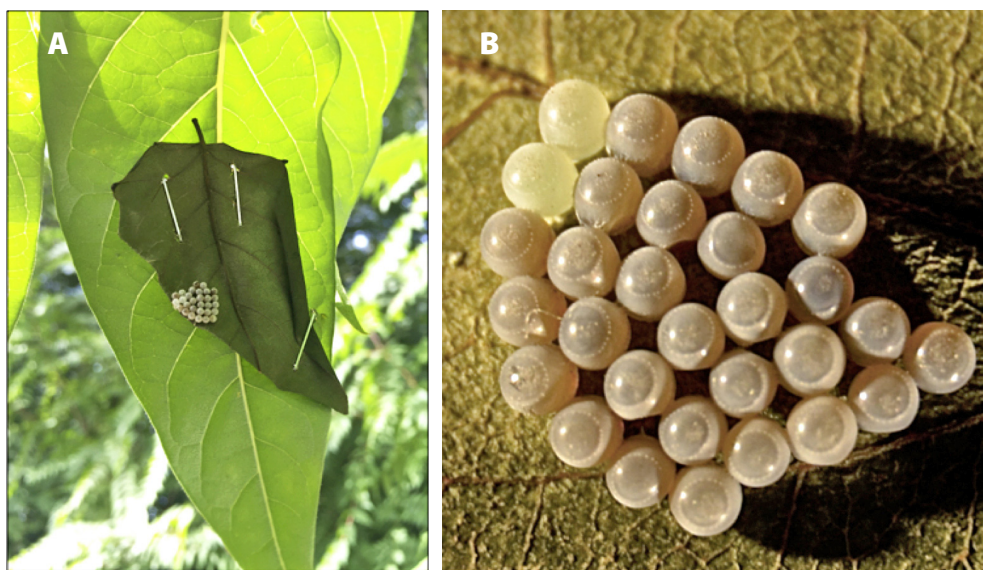


Figure 4. Newly placed (A) and parasitized BMSB sentinel eggs (B). [Photo: HVRL, Highland, NY]



Figure 5. A female Samurai Wasp, *Trissolcus Japonicus*. [Photo: Steve Valley, USDA-ARS]

eggs on a 5-day schedule until the end of September (Figure 4). During the week of 15 August, parasitism by Samurai Wasp occurred, as evidenced by adult wasp emergence on 7 September. Wasp individuals from sentinel eggs were sent to Elijah Talamas, USDA-ARS, who confirmed them to be *Trissolcus japonicus* (Figure 5).

In 2017, sentinel BMSB egg clusters were placed in nine western New York (WNY) sites by Art Agnello (NYSAES-Geneva), Tessa Grasswitz (CCE-Lake Ontario Fruit Program) and Deborah Breth, (CCE-LOFT Retired) in Monroe, Ontario, Orleans and Wayne counties, and a northern Ulster County site, mostly along the wooded edges of vegetable fields or orchards, beginning on 23 June (Table 1). During the season, we began seeing the Samurai Wasp oviposit in sentinel eggs placed in the field during the week of 7 July, and emerging on 23 July. However, the only site in which we observed Samurai Wasp was the Ulster county site in Marlboro (Hepworth), where *T. japonicus* is already present and was captured the previous year.

Native parasitoids were also found in the initial sentinel egg placement. This occurred at the Marlboro site in 2017, in which *Trissolcus euschisti* and *Telenomus podisi* emergence occurred on 23 and 30 May, respectively. The use of frozen eggs in the field provided for high levels of successful emergence of *T. euschisti* (73.1%) when compared with fresh BMSB eggs used in laboratory rearing (18.9%). However, offspring of *T. podisi* emerging from frozen BMSB eggs were few (6.9%) compared with *T. euschisti*, suggesting relatively low impact on BMSB by both of these native parasitoids in comparison with *Trissolcus japonicus* emergence from fresh BMSB eggs (68.8%). The parasitoid *Telenomus podisi* was also observed emerging from BMSB sentinel eggs placed in WNY on 24 August from

Kendall, Orleans County, yet none of the WNY sites captured *Trissolcus japonicus* during our 2017 survey.

Transport and Release of the Samurai Wasp in New York State

During conversations with the Environmental Protection Agency and the NYS Dept. of Ag. & Markets regarding obligations to work within the constraints of laws pertaining to the moving of wildlife, it fell upon the Dept. of Environmental Conservation (DEC) to decide whether a permit was required for the transportation and liberation of wildlife in regards to the adventive Samurai Wasp. Upon review, in a letter issued by Joseph E. Therrien on 28 July 2017, the DEC concluded that their statutory and regulatory framework around the Liberation of Wildlife Permit regulating release of biologicals, such as insects, does not generally apply to releasing insects into the wild, as long as the proposed release is not of an insect that is listed on either the endangered and threatened or invasive species listings identified in 6 NYCRR Parts 182 & 575. Release of the Samurai Wasp is further constrained by meeting other state, federal or local requirements and landowner permissions on all properties in which the wasp is released. With this decision allowing for transport, relocation, and use as a biological control agent, we began movement and release of the Samurai Wasp in NY agricultural locations.

We chose 32 NYS sites in close proximity to commercial farms in which to place *Trissolcus japonicus*-infested eggs (Figure 6). Beginning 15 September, we were able to place 87 BMSB clusters, totaling over 2300 eggs, in 6 NYS counties. A range of 1–3 egg clusters containing 22–86 individual eggs, were placed on plant hosts in each site, which included *A. altissima* (Tree

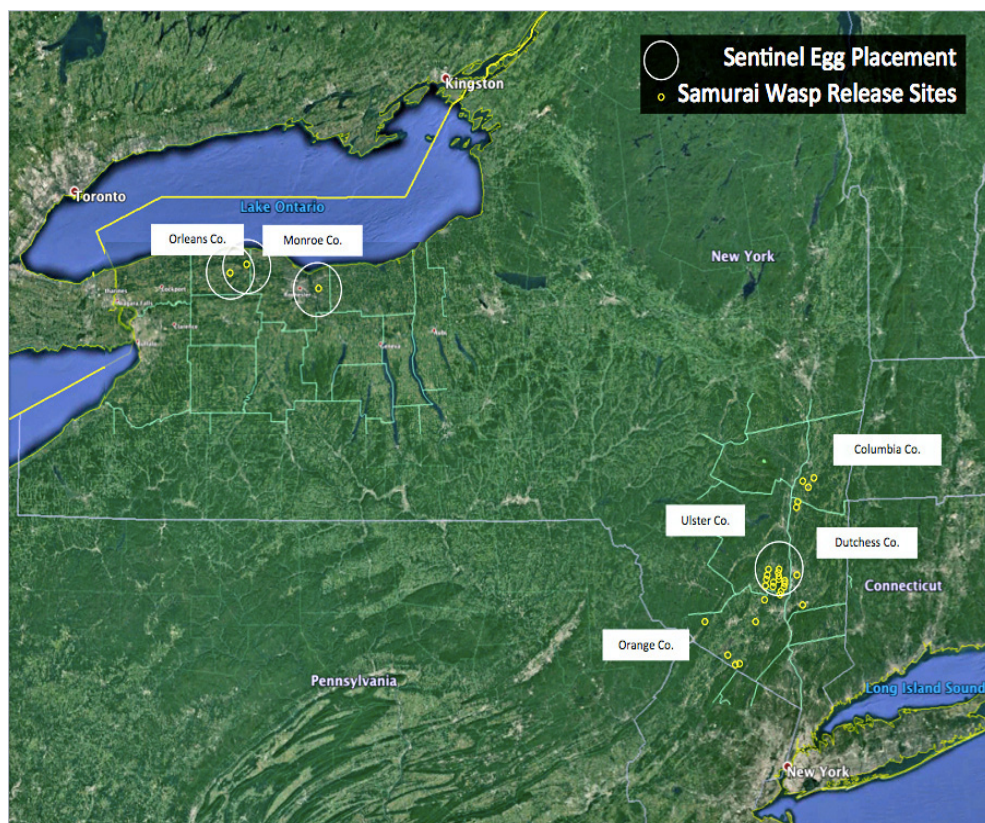


Figure 6. Samurai Wasp release sites in NYS.

of Heaven), *Acer saccharum* (sugar maple), *Catalpa speciosa* (catalpa), *Corylus avellana* (hazelnut), *Juglans nigra* (eastern black walnut), *Rhus sp.* (sumac), *Robinia pseudoacacia* (black locust) and *Vitis riparia* (native grape), all known hosts of BMSB (Table 1). Additionally, one site included placement onto deer fencing, with the eggs fixed to a petri dish and hung inverted to mimic the underside of foliage.

Successful Release of Samurai Wasp

In three WNY sites in which baseline sentinel egg data had been collected, the placement of *T. japonicus*-infested eggs coincided with the placement of sentinel eggs located 30 meters from the Samurai Wasp release site. In two of the three sites in Orleans and Monroe Counties, newly released *T. japonicus* were found parasitizing these sentinel eggs. Elijah Talamas, an entomologist

Table 1. Placement sites of *Trissolcus japonicus* parasitized eggs in NYS.

Site	Town	County	Date	Clusters	Eggs	Placement / Host Plant	Latitude	Longitude
1	Webster	Monroe	15-Sep	3	78	<i>Acer saccharum</i> (sugar maple)	43°11'3.78"N	77°26'56.76"W
6	Walden	Orange	22-Sep	2	54	<i>A. altissima</i> (Tree of Heaven)	41°33'1.34"N	74° 9'36.77"W
2	Holley	Orleans	22-Sep	3	84	<i>Juglans nigra</i> (eastern black walnut)	43°14'0.42"N	78° 1'10.46"W
3	Modena	Ulster	22-Sep	3	89	<i>Vitis riparia</i> (Native grape)	41°41'25.15"N	74° 4'3.51"W
4	New Paltz	Ulster	22-Sep	3	76	<i>Vitis riparia</i> (Native grape)	41°42'1.57"N	74° 4'24.22"W
5	Clintondale	Ulster	22-Sep	3	72	<i>Acer saccharum</i> (sugar maple)	41°41'32.91"N	74° 3'18.67"W
8	Warwick	Orange	23-Sep	2	56	<i>A. altissima</i> (Tree of Heaven)	41°13'55.83"N	74°22'0.66"W
9	Warwick	Orange	23-Sep	2	56	<i>A. altissima</i> (Tree of Heaven)	41°13'52.59"N	74°23'11.62"W
7	Gardener	Ulster	23-Sep	3	74	<i>Robinia pseudoacacia</i> (Black Locust)	41°40'14.72"N	74° 5'11.21"W
11	Hudson	Columbia	24-Sep	2	56	<i>Vitis riparia</i> (Native grape)	42°11'6.33"N	73°49'47.25"W
12	Hudson	Columbia	24-Sep	2	54	<i>A. altissima</i> (Tree of Heaven)	42°11'16.36"N	73°49'58.86"W
19	Valatia	Columbia	24-Sep	2	59	<i>A. altissima</i> (Tree of Heaven)	42°14'48.18"N	73°43'25.07"W
10	Fishkill	Dutchess	24-Sep	3	73	<i>Robinia pseudoacacia</i> (Black Locust)	41°31'12.02"N	73°49'40.04"W
17	Red Hook	Dutchess	24-Sep	3	73	<i>A. altissima</i> (Tree of Heaven)	42° 3'14.98"N	73°50'55.49"W
18	Tivoli	Dutchess	24-Sep	3	72	<i>Robinia pseudoacacia</i> (Black Locust)	42° 2'56.09"N	73°52'59.69"W
13	Marlboro	Ulster	24-Sep	2	56	<i>Rhus sp.</i> (Sumac)	41°38'13.67"N	74° 0'24.57"W
14	Milton	Ulster	24-Sep	3	78	<i>A. altissima</i> (Tree of Heaven)	41°39'4.29"N	73°59'33.93"W
15	Milton	Ulster	24-Sep	3	74	<i>Robinia pseudoacacia</i> (Black Locust)	41°38'43.94"N	73°59'24.84"W
16	Modena	Ulster	24-Sep	2	59	<i>A. altissima</i> (Tree of Heaven)	41°40'1.19"N	74° 7'44.19"W
20	Milton	Ulster	26-Sep	3	87	<i>Acer saccharum</i> (Sugar Maple)	41°38'39.48"N	73°58'6.6"W
21	Poughkeepsie	Dutchess	28-Sep	3	76	<i>Robinia pseudoacacia</i> (Black Locust)	41°40'40.28"N	73°53'50.91"W
22	Clintondale	Ulster	29-Sep	3	82	<i>Acer saccharum</i> (Sugar Maple)	41°40'39.00"N	74° 3'19.43"W
23	Clintondale	Ulster	29-Sep	3	84	<i>Vitis riparia</i> (Native Grape)	41°40'24.16"N	74° 3'30.29"W
24	Highland	Ulster	29-Sep	3	84	<i>Catalpa speciosa</i> (Catalpa Tree)	41°41'59.76"N	74° 3'7.90"W
25	Modena	Ulster	29-Sep	2	58	<i>Robinia pseudoacacia</i> (Black Locust)	41°40'6.74"N	73°59'39.28"W
26	New Paltz	Ulster	29-Sep	3	81	<i>Juglans nigra</i> (eastern black walnut)	41°42'43.82"N	74° 6'48.75"W
27	New Paltz	Ulster	29-Sep	3	86	<i>Juglans nigra</i> (eastern black walnut)	41°41'30.84"N	74° 7'43.96"W
28	Campbell Hall	Orange	6-Oct	3	71	Deer Fence	41°25'36.84"N	74°14'21.00"W
29	Cuddebackville	Orange	6-Oct	3	71	<i>Corylus avellana</i> (Hazelnut)	41°27'45.22"N	74°36'57.16"W
30	Cuddebackville	Orange	6-Oct	3	74	<i>Corylus avellana</i> (Hazelnut)	41°27'41.78"N	74°36'57.28"W
31	Cuddebackville	Orange	6-Oct	3	77	<i>Corylus avellana</i> (Hazelnut)	41°27'40.97"N	74°36'52.20"W
32	Warwick	Orange	6-Oct	3	76	<i>Acer saccharum</i> (sugar maple)	41°17'31.47"N	74°26'15.06"W

at USDA-ARS, confirmed the specimen wasps to be *Trissolcus japonicus*, verifying the successful release, movement and presence of the wasp in these two sites now moving into their overwintering phase.

Upon retrieval of the infested clusters from 11 of the 32 sites this fall, we recovered only 77% of the eggs. This was due in part to abscission of the host leaf, removal of eggs from the leaf, and predatory feeding by other insects such as ants. In 3 of the 11 sites, we observed newly emerged Samurai Wasps guarding the egg clusters. This is not unusual for Samurai Wasp behavior, as newly emerged males will wait for the emergence of the female, while females often guard parasitized eggs, securing their progenies' successful development. During our assessment of *T. japonicus*-parasitized egg release, we also found 168, or 24.4% (N=719), successfully emerged as adults, with 0.7% partially emerged from the egg, while 66.4% of the eggs showed no sign of emergence. These non-emergent eggs were both parasitized and unsuccessful in development (94.6%, having a dark hue) or were initially un-parasitized by the laboratory female wasps prior to field deployment (5.4%, white in color).

Determining the Overwintering Success of the Samurai Wasp

In the spring of 2018, we plan to place sentinel eggs weekly in each of the 32 sites, in an effort to recapture the Samurai Wasp. Determining the presence of the wasp next season would confirm successful overwintering of the parasitoid. However, in sites where confirmation is unsuccessful, we plan to re-apply BMSB eggs parasitized by *T. japonicus*, to promote the establishment of biological control in that site. We hope further to establish the presence of the wasp in the urban and suburban environment, so as to reduce overwintering populations of BMSB in homes, offices and storage facilities.

The Downside

Over the past 100 years, classical biological control has been used in efforts to manage agricultural pests. These efforts have at times been successful, but have not been without their failures. The complex of invasive pests is on the rise, causing significant losses and increased risk from elevated use of pest control measures. The recent emergence of the Samurai Wasp may prove to be a very welcome Asian warrior, now present in New York State.

The Samurai Wasp has been under lab quarantine for many years, beginning under the direction of Kim Hoelmer (Beneficial Insects Introduction Research Lab, USDA-ARS, Newark, Delaware), who first identified and transported the wasp and studied its host range for parasitism of native stink bugs in the US. Studies continue, to better understand the host preference capacity of Samurai Wasp. From these initial studies, *Trissolcus japonicus* is now known to attack brown marmorated stink bug, *Halyomorpha halys*, and a native species, *Podisus maculiventris* (Say). Evaluations employing choice tests and field surveys in laboratory studies conducted in China concluded that the ecological host range of *Trissolcus japonicus* does include several Pentatomidae species other than BMSB, such as *Dolycoris baccarum* (L.), *Erthesina fullo* (Thunberg), *Plautia fimbriata* (Fabr.) (Haye 2014) and *Glaucias subpunctatus* (Walker) (Matsuo et al. 2016).

Acknowledgements

We would like to thank the New York Apple Research and Development Program, New York Farm Viability Institute, and the New

York State Specialty Crop Research Initiative Grants Program for their generous funding support in the development and implementation of this project. We thankfully applaud Crist Brothers Orchards, Liberty Orchards and Minards Orchards for their willingness in partnering with us, and allowing us to utilize plantings over the past two seasons, along with the technical support from staff at the Hudson Valley Research Laboratory including Dana Acimović, Christopher Leffelman, Lucas Canino, Albert Woelfersheim and Erica Kane.

References

- Haye, T. 2014. Seasonal field parasitism of *Halyomorpha halys* and co-occurring non-target species in China. Brown Marmorated Stink Bug Working Group Meeting, Georgetown, DE.
- Hoebeke, E.R., and Carter, M.E. 2003. *Halyomorpha halys* Stål (Hemiptera: Pentatomidae), a polyphagous plant pest from Asia newly detected in North America. Proc. Entomol. Soc. Wash. 105: 225–237.
- Jentsch, P. J. 2017. Establishing the Samurai Wasp in NY Orchards. October 4, 2017. <https://blogs.cornell.edu/jentsch/author/pjj5-2/>
- Matsuo, K., Honda, T., Itoyama, K., Toyama, M., and Hirose, Y. 2016. Discovery of three egg parasitoid species attacking the shield bug *Glaucias subpunctatus* (Hemiptera: Pentatomidae). Jpn. J. Appl. Entomol. Zool. (in Japanese, English abstr.) 60: 43–45.
- Milnes, J. M., Wiman, N. G., Talamas, E. J., Brunner, J. F., Hoelmer, K. A., Buffington, M. L., and Beers, E. H. 2016. Discovery of an exotic egg parasitoid of the brown marmorated stink bug, *Halyomorpha halys* (Stål) in the Pacific Northwest. Proc. Entomol. Soc. Wash. 118.
- Northeast IPM Center. 2017. <http://www.stopbmsb.org/where-is-bmsb/state-by-state/>
- Orr, D. B. 1988. Scelionid wasps as biological control agents: A review. Fla. Entomol. 71: 506–528. <http://dx.doi.org/10.2307/3495011>
- Safavi, M. 1968. Chapitre 4. Biologie et écologie des *Trissolcus* en Iran. A. Développement des *Trissolcus*. In: Étude Biologique et Ecologique Des Hyménoptères Parasites Des Oeufs Des Punaises Des Céréales. Entomophaga 13(5): 422–439.
- Talamas, E.J., Herlihy, M.V., Dieckhoff, C., Hoelmer, K.A., Buffington, M., Bon, M.C., and Weber, D.C. 2015. *Trissolcus japonicus* (Ashmead) (Hymenoptera: Scelionidae) emerges in North America. J. Hymenopt. Res. 43: 119–128.
- Wilson, J., Gut, L., Haas, M., Grieshop, M., Poley, K., and Shane, W. 2016. Managing Brown Marmorated Stink Bug in Michigan Orchards, Mich. State Univ. Ext. <http://www.treefruit.msu.edu/extension/BMSBMngtGuideTreeFruit2016.pdf>
- Yang, Z.-Q., Yao, Y.-X., Qiu, L.-F., and Li, Z.-X. 2009. A new species of *Trissolcus* (Hymenoptera: Scelionidae) parasitizing eggs of *Halyomorpha halys* (Heteroptera: Pentatomidae) in China with comments on its biology. Ann. Entomol. Soc. Am. 102: 39–47.

Peter Jentsch is a Senior Extension Associate in Cornell's Department of Entomology at the Hudson Valley Research Laboratory specializing in arthropod management in tree fruits, grapes and vegetables.

NYSHS

New York State Horticultural Society

**EDUCATING, PROMOTING and PROTECTING
New York's Commercial Fruit Industry**



*Best Wishes for a
Happy Holiday Season,
and a Healthy and Prosperous
New Year to Come.*